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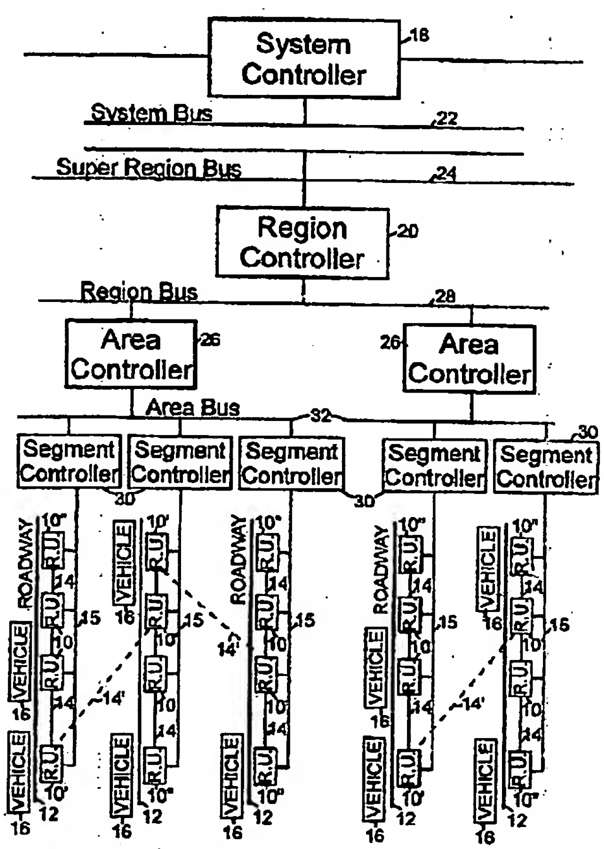
(57) Abstract

A transport system which includes a communications network and one or more vehicles each having an on-board control and data exchange unit, wherein the communications network includes a transport control unit; and a plurality of road units (10) arranged in series along a vehicle travel route, each road unit being adapted for communication with the transport control unit so as to exchange data therewith, and being further adapted for direct communication with at least two road units positioned adjacent thereto, wherein the on-board control and data exchange unit includes transceiver apparatus for communicating with each of the plurality of road units in series while traveling therepast; data processing apparatus connected to the transceiver apparatus; and control apparatus, connected to the data processing apparatus for selectably controlling and sensing any of a predetermined plurality of vehicle operating functions in response to signals received by the transceiver apparatus from the road units.



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TRANSPORT SYSTEM

FIELD OF THE INVENTION

The present invention relates to automated transport systems in general, and, in particular, to automated road vehicle transport systems.

BACKGROUND OF THE INVENTION

There are various problems associated with road transport. Among these problems are road accidents caused by human-related factors, such as tiredness, loss of control, a slow reaction time, limited field of view, insufficient maintenance of distance between vehicles, and inattention to traffic signs. A further transport-related problem is that of loss of time which may be caused by slow driving speed due to weather conditions, road conditions, visibility, and traffic congestion, for example. Unfamiliarity with the route may also cause a loss of time.

Apart from the inconvenience which may be caused by any of the above factors, these factors also represent a huge economic burden on developed society. If for these reasons alone, it would be desirable to provide an automated traffic system which substantially reduced the above problems.

During recent years the development of automated traffic systems has received increased attention, and substantial effort has been invested in trying to find a solution to problems such as those outlined above.

Two articles, entitled 'The Intelligent Vehicle-Highway

Systems Program in the United States' and 'RTI/IVHS on European Highways' appear in the ITE 1993 Compendium of Technical Papers. These articles give a general overview of programs that are being developed and the aims of these programs, in the United States and Europe.

These programs, which relate to IVHS (intelligent vehicle-highway systems), are concerned with a wide range of different aspects of automation, such as, automatic vehicle identification for purposes of automatic tolling on toll roads; relaying of up-to-date information to drivers in order to improve their decision-making ability; and automatic driving systems.

Among various systems that have been developed are the following:

satellite-based vehicle navigation systems;

traffic management systems based on a local and international integrated sensing and communications systems for passing information to drivers on road and traffic conditions, and for controlling traffic lights and electronic signs;

two-way communications systems with drivers via radio beacons and transponders located by the side of the road or beneath it - these systems can automatically identify vehicles and broadcast thereto a wide range of different types of information, such as navigational instructions, traffic conditions, and the like; and

automatic driving based on an on-board computerized control system, and on radio connection between vehicles and sensing devices for measurement of the inter-vehicle distance, wherein

travel is carried out in 'platoons', wherein each platoon has predetermined travel and communication procedures. Platoon-oriented systems are described in a paper entitled 'Sketch of an IVHS Systems Architecture', published by the Institute of Transportation Studies of the University of California, Berkeley.

While each system has its advantages and disadvantages, none of the systems known to the present Applicant constitutes a comprehensive answer to the problems outlined above.

An indication of the state of the art is provided by published PCT application no. PCT/US91/08892, publication no. WO 92/09941, entitled "Downward Compatible AGV System and Methods." This publication discloses an automated guided vehicle (AGV) control system which is downward compatible with existing guidewire systems providing both guidewire navigation and communication and guidance and wireless communication between a central controller and each vehicle, Autonomous vehicle navigation comprises travel over paths marked by update markers which may be spaced well apart, such as 50 feet (about 16 m).

Redundant measurement capability comprising inputs from linear travel encoders from the vehicle's drive wheels, position measurements from update markers, and bearing measurements from a novel angular sensing apparatus, in combination with the use of a Kalman filter, allows correction for navigation and guidance errors caused by such factors as angular rate sensor drift, wear, temperature changes, aging, and early miscalibration during vehicle operation. The control system comprises high frequency two-way data transmission and reception capability over the guidewires and via wireless communications. The same data rates

and message formats are used in both communications systems.

The above-outlined system is intended for purpose-built vehicles used in a warehouse situation. Accordingly, while addressing certain points of automated control of vehicles, it does not provide a solution to the various transport related problems discussed herein.

SUMMARY OF THE INVENTION

The present invention aims to provide an automated road-vehicle transport system which optimizes travel, in terms of speed, safety and economy, thereby significantly reducing problems associated with and caused by non-automated road-vehicle transport systems.

The present invention further seeks to provide an automated road-vehicle transport system which provides a comprehensive solution to known traffic problems, in contrast to prior art automated systems which address certain aspects of traffic problems only.

An additional aim of the invention is to provide a vehicle wherein, by means of an on-board communications and control system, the vehicle is able to become integrated with the automated transport system of the invention.

There is thus provided, in accordance with a preferred embodiment of the invention, a transport system which includes a communications network and one or more vehicles each having an on-board control and data exchange unit,

wherein the communications network includes a transport control unit; and a plurality of road units arranged in series along a vehicle travel route, each road unit being adapted for communication with the transport control unit so as to exchange data therewith, and being further adapted for direct communication with at least two road units positioned adjacent thereto,

and wherein the on-board control and data exchange unit

includes transceiver apparatus for communicating with each of the plurality of road units in series while traveling therepast; data processing apparatus connected to the transceiver apparatus; and control apparatus, connected to the data processing apparatus for selectably controlling and sensing any of a predetermined plurality of vehicle operating functions in response to signals received by the transceiver apparatus from the road units.

Preferably, the road units are arranged along a predetermined path along the travel route and are operative, in conjunction with the on-board unit, to enable a predetermined positioning of the vehicle relative to the predetermined path.

Further in accordance with a preferred embodiment of the invention, the on-board control and data exchange unit and each the road unit cooperate together so as to enable the predetermined positioning of the vehicle.

Additionally in accordance with a preferred embodiment of the invention, the on-board control and data exchange unit also includes first antenna apparatus mounted in a predetermined position on the vehicle and associated with the data processing apparatus, and wherein each the road unit includes second antenna apparatus, wherein a predetermined one of the first and second antenna apparatus includes a pair of antennae arranged in a predetermined orientation, there also being provided comparator apparatus, associated with the pair of antennae, for providing an output indication of the position of the vehicle relative to the predetermined path.

Further in accordance with a preferred embodiment of the invention, the pair of antennae and the comparator apparatus

form part of the on-board control and data exchange apparatus on the vehicle, and are connected to the data processing apparatus thereof.

Additionally in accordance with a preferred embodiment of the invention, the on-board control and data exchange unit also includes a main communications antenna connected to the transceiver apparatus, adapted to receive and transmit data messages between the data processing unit and the road units.

Further in accordance with a preferred embodiment of the invention, the transceiver apparatus is operative to provide signal outputs to the road units, the signal outputs including messages of a type selected from the group which consists of:

vehicle identification data;
messages indicative of vehicle operation parameters;
messages indicative of driver-vehicle inputs; and
driver-initiated data enquiry messages.

Additionally in accordance with a preferred embodiment of the invention, the road units are operative to transmit signals corresponding to the signal outputs from the transceiver apparatus to the transport control unit, and the data processing apparatus of the on-board control and data exchange unit includes first data processing apparatus,

and wherein the transport control unit includes communication apparatus for selectably communicating with each of the plurality of road units in response to reception of input signals therefrom; and second data processing apparatus, connected to the communication apparatus, for processing input

data corresponding to the input signals, and for providing output data for transmission by the communication apparatus to the road units in the form of output signals.

Further in accordance with a preferred embodiment of the invention, each of the road units is operative, in response to detection of passage of the vehicle, to transmit an output signal to at least an immediately adjacent downstream road unit, indicating travel of the vehicle toward the downstream unit.

Additionally in accordance with a preferred embodiment of the invention, each of the road units is operative, in response to one or more of vehicle operation parameter values or driver-vehicle input values outside of a predetermined range, to automatically transmit an emergency indication directly to one or more adjacent road units, these units being operative, in response to receipt of the emergency indication, to provide control signals to the transceiver apparatus of the on-board control and data exchange unit in accordance with the emergency indication.

Preferably, the road units to which the emergency indication is transmitted are operative also to provide control signals to the transceiver apparatus of the on-board control and data exchange unit of a plurality of vehicles whose travel data are affected by the vehicle whose parameter values or input values are determined to be outside the predetermined range.

Further in accordance with a preferred embodiment of the invention, the one or more adjacent units are operative, in response to reception of the emergency indication, to transmit a velocity control signal to the vehicle on-board unit.

Additionally in accordance with a preferred embodiment of the invention, a plurality of upstream road units and a plurality of downstream road units, relative to the automatically transmitting road unit, are operative to activate immediately adjacent road units so as to transmit velocity control signals to a plurality of on-board units located on the plurality of vehicles whose travel data are affected by the vehicle whose parameter values or input values are determined to be outside the predetermined range.

Further in accordance with a preferred embodiment of the invention, the transceiver apparatus of the on-board control and data exchange unit is operative to provide intermittent probing signals as the vehicle travels along the travel route, and wherein the road units include apparatus for detecting the probing signals and for triggering the road units in response thereto.

There is also provided, in accordance with an alternative preferred embodiment of the invention, a transport system which includes:

a network of intersecting travel routes;

a plurality of vehicles each adapted for travel along any selected travel route; and

a control system for controlling travel of each of the plurality of vehicles simultaneously, wherein travel parameters of each the vehicle are determined in accordance with travel parameters of others of the vehicles.

Additionally in accordance with a preferred embodiment

of the invention, the control system includes a communications network which includes:

a plurality of transport control units, each adapted to control travel of the plurality of vehicles along travel routes in a predetermined geographical zone; and

a plurality of road units arranged in series along the intersecting travel routes, each road unit being adapted for communication with the transport control unit so as to exchange data therewith, and being further adapted for direct communication with two or more road units positioned adjacent thereto, and wherein

each vehicle has an on-board control and data exchange unit which includes:

transceiver apparatus for communicating with each of the plurality of road units in series while traveling therepast;

data processing apparatus connected to the transceiver apparatus; and

control apparatus, connected to the data processing apparatus for selectably controlling and sensing any of a predetermined plurality of vehicle operating functions in response to signals received by the transceiver apparatus from the road units,

wherein the road units are arranged along predetermined paths along the intersecting travel routes and are operative, in conjunction with the on-board unit of each the vehicle, to enable a predetermined positioning thereof relative to the predetermined path.

Further in accordance with a preferred embodiment of

the invention, there are also provided end road units similar to the plurality of road units, but adapted for communication with a single adjacent road unit only.

Additionally in accordance with a preferred embodiment of the invention, the on-board control and data exchange unit and each the road unit cooperate together so as to enable the predetermined positioning of the vehicle.

Further in accordance with a preferred embodiment of the invention, the transceiver apparatus is operative to provide signal outputs to the road units, the signal outputs including messages of a type selected from the group which consists of:

vehicle identification data;

messages indicative of vehicle operation parameters;

messages indicative of driver-vehicle inputs; and

driver-initiated data enquiry messages.

Additionally in accordance with a preferred embodiment of the invention, the road units are operative to transmit signals corresponding to the signal outputs from the transceiver apparatus to the transport control unit, and the data processing apparatus of the on-board control and data exchange unit includes first data processing apparatus,

and wherein the transport control unit includes:

communication apparatus for selectably communicating with each of the plurality of road units in response to reception of input signals therefrom; and

second data processing apparatus, connected to the communication apparatus, for processing input data corresponding

to the input signals, and for providing output data for transmission by the communication apparatus to the road units in the form of output signals.

Further in accordance with a preferred embodiment of the invention, the system further includes an additional transport control level operative to control the plurality of transport control units, wherein each the additional level has one or more higher control units, each of which includes:

communication apparatus for selectably communicating with each of the plurality of transport control units in response to reception of input signals therefrom; and

third data processing apparatus, connected to the communication apparatus of the higher control unit, for processing input data corresponding to the input signals, and for providing output data for transmission by the communication apparatus to the transport control units in the form of output signals.

Additionally in accordance with a preferred embodiment of the invention, the system further includes a plurality of hierarchical control levels, each operative to control a control level immediately therebeneath in the hierarchy, each the hierarchical control level including:

one or more communications apparatuses for selectably communicating with a control level immediately therebeneath in response to reception of input signals therefrom; and

one or more data processing apparatuses, connected to each the communication apparatus of the hierarchical control level, for processing input data corresponding to the input

signals, and for providing output data for transmission by the communication apparatus to the control level immediately therebeneath in the form of output signals.

Additionally in accordance with a preferred embodiment of the invention, and wherein each transport control unit is operative to receive data messages originating from the on-board unit of a vehicle travelling in the geographical zone of that transport control unit, and wherein, if the data message relates to a geographical zone other than that of that transport control unit, the communications apparatus of the transport control unit is operative to transfer the data message to the transport control unit of the level immediately above.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more fully understood and appreciated from the following detailed description, taken in conjunction with the drawings, in which:

Fig. 1 is a block diagram illustration of a transport system, constructed and operative in accordance with a preferred embodiment of the present invention;

Fig. 2 is a diagrammatic representation of a geographical area in which the system of the invention has been installed, illustrating the hierarchical nature of the system;

Fig. 3 is a schematic illustration of a plurality of different types of intersecting roadways in which a communication network has been installed;

Fig. 4A is a block diagram illustration of an on-board vehicle control and data exchange unit constructed in accordance with a preferred embodiment of the present invention;

Fig. 4B is a schematic plan view of a vehicle arranged so as to be longitudinally centered over the longitudinal axis of a roadway lane, in accordance with the present invention;

Fig. 5 is a block diagram illustration of a road unit constructed in accordance with a preferred embodiment of the present invention;

Fig. 6A is a schematic block diagram illustration of a segment controller shown in Fig. 1, in accordance with a preferred embodiment of the invention;

Fig. 6B is a diagrammatic representation of routine communications between a segment controller and the road units

associated therewith;

Fig. 7 is a schematic block diagram illustration of an area controller shown in Fig. 1, in accordance with a preferred embodiment of the invention;

Fig. 8 is a schematic block diagram illustration of a system controller shown in Fig. 1, in accordance with a preferred embodiment of the invention;

Fig. 9 is a diagrammatic illustration of a a multi-lane highway in which is employed the transport system of the present invention;

Fig. 10 is a schematic view of a four-way junction showing the layout of system components thereat;

Fig. 11 is a series of graphs depicting communications timing between a vehicle traveling at a velocity of 200 kph and a series of road units of the system of the invention; and

Fig. 12 is a flow chart diagram of an emergency braking procedure, in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

It will be appreciated from the ensuing description that the present invention provides an automated road-vehicle transport system which optimizes travel, in terms of both speed, safety and economy, thereby providing a comprehensive solution to many problems associated with and caused by non-automated road-vehicle transport systems. The present system also provides a solution that is therefore more comprehensive than any of those suggested in the prior art.

The system of the present invention has the following capabilities:

1. automatic and optimal navigation - taking into account both travel time and driving conditions on alternative routes;
2. fully automatic driving on main highways, multi-lane routes, single lane or narrow routes and junctions;
3. bi-directional communications via a communications network connecting drivers, automatic vehicle driving systems, sensory devices and installations (weather etc.), a hierarchy of transport control centers, and stationary addresses such as vehicle fleet owners, individuals and government bodies;
4. real time identification and location of individual vehicles; and
5. automatic toll levying.

It will further be appreciated that on routes encompassed by the system of the invention traffic signs and signals are rendered redundant. To the extent that routes not encompassed by the system are integrated into the system,

selectable manual control, in predetermined situations is retained. The present system is also constructed so as to enable the addition of further control and communications features.

Referring now to Fig. 1, there is shown a transport system, constructed and operative in accordance with a preferred embodiment of the present invention. The transport system of the invention includes a control network which includes a plurality of road units 10, arranged in series along a vehicle travel route or roadway, referenced 12. Road units 10 are denoted by the initials "RU" in Fig. 1.

The road units are arranged in series along a multi-channel communications cable, shown schematically at 13 (Figs. 3 and 10), and are operative to communicate both with vehicles 16 traveling along roadway 12, and with transport control units at various hierarchical levels, as described below. Communication between road units 10 and the transport control unit is carried out via a communications bus 15.

Communications cable 13 contains, in a single cable construction, a plurality of road units 10 which are connected via a serial link, referenced 14, for direct serial communications between road units 10. Cable 13 further includes various parallel buses serving the transport control units at the various hierarchical levels of the present system.

The described arrangement, whereby each road unit 10 is connected via serial link 14 in a straight line, ensures the fast and immediate transfer of information both in the direction of the flow of traffic and in the reverse direction, and is

operative to control the local speed of the vehicles, turns (passage between lanes and exiting from the road), emergency braking, and various other situations whereby a local, "reflex" type decision is required.

The control network is divided up into different hierarchical levels, each successive level encompassing a successively larger geographical area of roadways or routes.

Referring now also to Fig. 2, it is seen that each geographical portion is a constituent division of a larger portion. It is thus seen that the largest portion, labeled "S", represents the highest level in the example and geographically encompasses the entire transport system of the invention. Portion S is controlled by a system controller, seen at 18 in Fig. 1, and is divided into regions labeled "R1", "R2", ..., "Rn", each of which is controlled by a region controller, seen at 20 in Fig. 1.

Communications between each region controller 20 and the system controller 18 is by an appropriate parallel communications channel, typically a bus. As seen in Fig. 1, this may either be a system bus 22, or, if one or more intervening levels of control are interposed between the region controllers 20 and system controller 18, there may also be one or more intervening communications buses. This is indicated by the 'super region bus' 24 in Fig. 1.

As seen in Fig. 2, each region is divided into areas, labeled "A1", "A2", "A3", ..., "An", each of which is controlled by an area controller, seen at 26 in Fig. 1. Region controller 20 communicates with its constituent area controllers 26 via a 'region' communications bus 28. Finally, each area is divided

into segments labeled "S1", "S2", ..., "Sn", each of which comprises a plurality of road units 10 (Fig. 1) controlled by a segment controller, seen at 30 in Fig. 1. Communication between each segment controller 30 and area controller 26 is via an 'area' communications bus 32. Road units 10 communicate with an associated segment controller 30 via a segment communications bus 15. This is parallel to inter-road unit communications which, as described are carried out via serial link 14.

The controllers at the various levels, via the various parallel communication channels or buses, are responsible for management of the system. This includes a variety of function, which include, by way of example, planning and control of vehicle routes, planning and management of the average journey speeds on different roads, receipt and delivery of messages, processing of information on driving conditions (weather, accidents, traffic jams and so on), and debiting on toll roads. These functions are exemplified in greater detail hereinbelow.

It will be appreciated that the highest level of control need not be that represented by portion S, but, as the need arises and as the geographical extent of the system is extended, successively higher levels of control may be added.

The distribution of road units 10 along different types of roadway 12, is seen schematically in Fig. 3. This is described more fully hereinbelow.

Briefly, the function of each road unit 10 is to communicate with vehicles 16, as described hereinbelow in detail, and with an associated segment controller 30 so as to exchange

data therewith, thereby also permitting, inter alia, the exchange of data between the control network and individual vehicles. Each road unit 10 is further operative to communicate with at least two road units positioned adjacent thereto. This too is described in detail hereinbelow.

Referring now to Fig. 4A, a vehicle 16 forming part of the present system is equipped with an on-board control and data exchange unit referenced generally 34 which is operative both to communicate with the communication network via road units 10 (Fig. 1), and also to navigate and generally control the vehicle.

Unit 34 is selectably actuable via an on-off power switch 35, and includes a transceiver 36 for communicating with road units 10 while traveling therepast, a data processor 38 connected to transceiver 36, and a control unit 40. A control unit or interface 40 is connected to data processor 38 for coordinating between data processor 38 and the various vehicle operating and sensory functions, such as, steering, braking, acceleration, transmission, lights, fuel level, engine temperature, and oil pressure.

Thus the system is able to control any of a predetermined plurality of vehicle operating functions independently and in response to signals received by transceiver 36 from the communications network via road units 10. The precise manner in which vehicle functions are controlled and monitored may be substantially as described in published PCT application no. PCT/US91/08892, publication no. WO 92/09941, entitled "Downward Compatible AGV System and Methods," the contents of which are incorporated by reference. Accordingly, as vehicle

function control is thus known in the art, it is not necessary to describe it specifically herein.

In order to be able to permit fully automatic safe operation of vehicle 16 via the transport system, several factors, including, inter alia, the location, speed, and orientation of the vehicle, must be known at all times. Referring now also to Fig. 4B, determination of the position of the vehicle on a roadway is facilitated by first, positioning communications cable 13 along the longitudinal axis 42 of a roadway 12 or of a lane portion thereof, referenced 'L' (Fig. 3) and, second, by centering of the vehicle 16 over communications cable 13, thereby to provide a corresponding centering of the vehicle over the longitudinal axis 42 of a roadway or lane. Preferably, cables 13 are buried beneath the asphalt or concrete road surface.

In order to center vehicle 16 over cable 13, on-board unit 34 further has a pair of antennae 44 which are aligned symmetrically about the longitudinal axis 46 (Fig. 4B) of vehicle 16. The antennae 44 are adapted to detect a signal, preferably a radio signal, emitted by a road unit 10 as the vehicle travels thereover. Each antenna 42 is connected to a comparator 48 (Fig. 4A) via a receiver 50. Upon receiving signals from road unit 10 via antennae 44 and receivers 50, the comparator 48, which may be a phase or amplitude comparator, is operative to compare the signals and to generate an error signal output which is provided to data processor 38. The value of the error signal thus provided indicates the position of the vehicle 16 with respect to communications cable 13. When the vehicle is properly centered,

the error signal approximates to zero.

If the error signal is found to indicate that the vehicle is not properly centered, data processor 38 is operative to drive control interface 40 so as to operate the vehicle, via any of the vehicle control systems, such as, steering, brakes, fuel pedal, thereby to properly center the vehicle.

Preferably, the longitudinal reception range (typically 1.2 meters) of the two centering antennae 44 overlaps the beginning of the longitudinal reception range of a main communications antenna 56, so that at any speed the centering antennae 44 will receive at least one response transmission from each road unit 10.

It will thus be appreciated that the centering is carried out via interaction between the on-board unit 34 and road unit 10. Centering may thus be performed fully automatically, as described above. Alternatively, centering may be carried out non-fully automatically, with a man-in-the-loop, whereby driving adjustments required to properly center the vehicle are displayed on a visual display unit 52 and/or provided as audible instructions via a speaker 54, thereby enabling a person operating the vehicle to perform the necessary position adjustments. Both visual display unit 52 and speaker 54, where provided, are connected to the data processor 38. It will be appreciated that, as centering is carried out in real time, while the vehicle 16 proceeds along the roadway 12, the on-board unit 34 operates in conjunction and communicates with a plurality of road units 10 in succession.

In addition to the two antenna 44 which serve for

centering vehicle 16, there is also provided a main communications antenna, referenced 56. Antenna 56 is connected to transceiver 36 and is operative to transmit probing signals (as described below) and to receive and transmit data messages between data processor 38 and road units 10.

It will be appreciated by persons skilled in the art that while it is preferred to provide separate centering and communications antennae, in accordance with an alternative embodiment of the invention, these functions may be combined such that a pair of antennae is provided which serve both for centering and for other communications.

Referring now to Fig. 5, there is shown a road unit 10, constructed and operative in accordance with an embodiment of the invention. Each road unit 10 includes an antenna 58, a transceiver 60, typically a radio transceiver, and a data processor 62. Data processor 62 is also connected to a segment controller 30 via segment communications bus 15 and a parallel bus interface 64, and is further connected to at least two adjacent road units via two or more serial transceivers 66.

Road unit 10 typically does not transmit signals via transceiver 60 unless triggered by a probing signal emitted from a vehicle on-board unit 34. Accordingly, a detection and triggering device 65 is provided which is operative to activate road unit 10 so as to communicate with the on-board unit 34 and to instruct it to perform any of the vehicle functions described below.

Referring now briefly to Figs. 6A, 7 and 8, there are

respectively shown a segment controller 30, an area controller 26 and a system controller 18, forming essential communications links in the hierarchy of the communications network of the present invention.

In Fig. 6A it is seen that segment controller 30 has a data processor 68 which interfaces with segment bus 15 (also seen in Fig. 1) via a segment bus interface 70, and further interfaces with area bus 32 (also seen in Fig. 1) via an area bus interface 72.

With reference now to Fig. 7 it is seen that area controller 26 (also seen in Fig. 1) has a construction analogous to that of segment controller 30. Accordingly, area controller 26 has a data processor 74 which interfaces with area bus 32 (also seen in Fig. 1) via an area bus interface 76, and further interfaces with region bus 28 (also seen in Fig. 1) via a region bus interface 78.

The structure of system controller 18, shown in Fig. 8, is seen to be generally analogous to both that of segment controller 30 and area controller 26, having a data processor 80 which interfaces with system bus 22 (also seen in Fig. 1) via a system bus interface 82. It will be appreciated that system bus 22 may interface directly with region controller 20 (Fig. 1). However, depending on the requirements of an individual system, there may be one or more intervening levels of communications between system controller 18 and region controller 20.

In Fig. 8 it is also seen that an inter-system communications link 84 may be optionally provided, wherein a plurality of transport systems may be interconnected so as to

exchange information between systems. This may be required over a very large area, such as a continental land mass, wherein effectively a single continuous network of roads may be governed by several systems constructed in accordance with the invention. While the communications between different hierarchical levels are typically by means of data buses, inter-system link 84 is preferably a telecommunications-type data exchange.

A method of effecting communications between segment controller 30 and its associated road units 10 is described below, in conjunction with Figs. 1, 5, 6A and 6B.

In general, the length of a segment can be several hundred meters and even a number of kilometers. The number of road units 10 in any given segment can thus be between several hundred and several thousand. In order to facilitate rapid communications between each segment controller 30 and its associated road unit 10, a communications network between each segment controller 30 and its associated road units 10, characterized by the following:

All the road units 10 and their associated segment controller 30 are connected via appropriate interfaces 64 (Fig. 5), in parallel, to a single pair of wires which constitutes segment bus 15.

The segment controller 30 is the master of the segment bus 15, and all the road units 10 are slaves, such that most routine communications are governed by the segment controller 30. With the exception of certain predetermined situations, such as the emergency braking procedure, described hereinbelow in conjunction

with Fig. 12, which is a quasi-reflexive procedure, the function of the road units 10 is to respond to vehicle on-board units 34 in accordance with instructions received from the controller 30.

Communication between controller 30 and its associated road units 10 is of necessity asynchronic. This is due mainly to different propagation times between road units located at different distances from the controller, and due to the fact that in order to conduct a sensible dialog between them, a given road unit and the controller have to receive complete messages from each other prior to responding.

A segment controller-road unit transmission includes the following parts:

A. A segment controller identification code.

B. The address or particular road unit or units to which the transmission is addressed. This can be any selected group of road units from a single specified road unit to the road units of the entire segment.

C. A message, containing information, instructions, or questions.

A road unit-segment controller transmission includes the following parts:

A. An identification code of the transmitting road unit.

B. An identification code of a vehicle for which the transmission (or report) has been generated. This does not apply in a situation wherein a transmission concerns non-vehicle related information, such as a report of faults, a self-check, and the like. Each type of information has its own predetermined code.

C. A message containing information, requests (from the driver) or questions.

When initiating a transmission to one or more road units 10, the segment controller 30 instructs a particular road unit or group of road units them what they are required to do. This may be routine reporting of vehicle travel, detailed reporting procedure, self-check procedure, change in function, and so on.

As an example, the case of an instruction to all road units to proceed with routine reporting is described below in conjunction with Fig. 6B. Fig. 6B is divided into transmission plots A - E, wherein A is a plot of controller-road units transmissions, B, C and D are plots of road unit response transmissions, and E is a combined plot, showing all transmissions between the controller and the road units. An instruction transmission from the controller to the road units is indicated at 150 in plot A of the drawing.

Immediately upon termination of its instruction transmission 150, the segment controller 30 begins to transmit clock pulses 152, preferably of polarity opposite to that of the instruction transmission.

Each clock pulse advances the address counter in each road unit data processor 62.

Each time that the address counter of a given road unit advances, as described, the road unit checks if the address currently indicated by counter corresponds to its own personal identification number. Preferably, the road units in the segment

are numbered sequentially.

If the address currently indicated by the counter is identical to its personal identification number, the road unit data processor 62 checks if it needs to pass on a message to the controller. If so, it will transmit its response, as seen at 154, 156 and 158 for respective road units "l", "m", and "n".. If not, it will not respond as, in the presently described routine mode, if no vehicle has passed over the road unit since it previous report, it does not need to transmit.

After each clock pulse 152, the controller waits for an answer, it being appreciated that the waiting time is predetermined in accordance with the longest propagation time in the segment. When there is an answer, the controller ceases to transmit clock pulses 152 and receives the answer. The answer has a defined structure such that the controller 30 identifies its end.

Immediately after termination of the answer, the controller resumes transmission of the clock pulses 152.

It will be appreciated that, in the above-described communications procedure, all the road units in the segment are given the option of reporting.

It should further be noted that, in parallel to the above-described communications procedure, the controller processes the information received from the road units and decides how to continue.

It is thus seen that the transport system of the present invention is based on communications (radio or otherwise) between vehicles 16 (Figs. 1, 4A and 4B) and a roadway-based

communications network, substantially as described above in conjunction with Figs. 1-8.

According to a preferred embodiment of the invention, road units 10 (Figs. 1, 3, 4A and 4B) broadcast short transmissions only in response to a triggering or probing signal emitted by the transceiver 36 (Fig. 4A) of a vehicle on-board unit 34 passing above them. As described, transmissions between on-board unit 34 road units 10 contain information, and signals enabling centering of the vehicle 16 over the line units 10.

Typical operations of the system of the invention are now described, it being understood that these represent an example only of the capabilities and applications of the invention.

Prior to and during a journey by a vehicle 16 having installed therein an on-board system 34 (Fig. 4A), a human operator, referred to below as "driver", can enter a desired destination into data processor 38 via a suitable manual data entry device 39. Typically device 39 is a suitable keyboard, although other suitable types of device, such as joystick- or mouse-based devices or an oral instruction-responsive device may additionally, or alternatively, be employed for this purpose.

By means of the communications system constituted by the visual display unit 52 and speaker 54, the driver is provided with visual or audio-visual instructions which details a journey route recommended by the system, taking into account geographical knowledge of the road system, topographical, present traffic, roadwork, and weather considerations.

It will be appreciated that the system can also be programmed to take account of many additional factors. Accordingly, since the system has extensive and up-to-date knowledge of road conditions and other variables affecting the journey, it is able to plan a route and optimum speeds for any vehicle, taking into account factors which include, inter alia, safety, time and cost.

The driver may accept the suggestion of the system or enter another route as he wishes. If his choice is possible taking into account driving conditions, it will be confirmed by the system. From this moment the driver can enter an "automatic driving" instruction via data entry device 39, thereby to transfer the vehicle 16 to automatic driving and to allow the system to drive the vehicle to the destination.

The driver can take control of the vehicle at any time by entering a predetermined "manual driving" instruction accordingly. This can be done, for example, by manual operation of any of the vehicle controls.

Referring now to Fig. 9, it is seen that a typical multi-lane highway, referenced 90, is divided into three lanes, labeled "lane 1", "lane 2" and "lane 3". Each lane has installed along its longitudinal axis, preferably beneath the surface thereof, a communications cable 13 (also seen in Figs. 3, 4A and4B). A predetermined length of communications cable 13, together with the road units 10 connected thereto, constitute a segment, substantially as described above in conjunction with Figs. 1 and 2.

In addition to the main, centrally-located

communications cables 13, there are also provided, in predetermined locations, branch communications cables, referenced 13a, 13b, 13c and 13d. These branch cables connect longitudinal cables 13 of parallel segments so as to enable passage of automatically controlled vehicles 16 (Figs. 1, 4A and 4B) from lane to lane or, in terms of the system, from segment to segment. In addition, one or more communication cables 13e may also be provided along the ramp 92 in order to allow automated entry to/exit from the highway 90.

Furthermore, as seen in Figs. 1 and 10, there may also be provided inter-segment serial links, referenced 14', via which instructions or data can be transmitted from one segment to an adjacent segment. This may be needed, for example, when a vehicle is being navigated from one lane to another, or when turning, or to warn road units 10 and vehicles in adjacent segments of an emergency situation.

Accordingly, while virtually all of road units 10 are connected in series to two adjacent (upstream and downstream) road units, a plurality of nodal road units, referenced 10', are connected additionally to road units in an adjacent branch communications cable, thereby enabling passage of vehicles 16 from lane to lane. It will be appreciated, however, that "end" road units, referenced 10" in Fig. 1, are connected to a single road unit only.

Normally, the vehicles 16 travel along a certain route which the system has provided for them according to certain criteria, which include:

the maximum speed of each vehicle,

the type or class of vehicle (trucks, private vehicles, public vehicles, and the like), and

predetermined turns depending on the route selected.

Turns from one lane into another and between different roadways, such as exemplified in Fig. 3, are preprogrammed by the controllers at the various system levels, substantially as described above in conjunction with Fig. 1.

"Turn" instructions are transferred as instructions for action to the road units 10 via the various system levels and, ultimately, via the segment controllers 30 (Figs. 1 and 6). Execution of turns in accordance with the turn instructions are managed "in the field" by the road units 10 and segment controllers 30. During execution of turns the road units 10 and segment controllers 30 take into account the operating conditions and spacing of vehicles in the vicinity of the turning vehicle, and how the turning of the turning vehicle will affect them.

"Unexpected" turns or stops are those which are neither planned nor executed by the system. Such turns are detected by the road units 10 and the system enters an emergency procedure, which may include stopping or diversion of other vehicles in the vicinity. Emergency procedures are described hereinbelow in conjunction with Fig. 12.

Referring now to Fig. 10, there is shown, in schematic form, the layout of system components at a four way junction, referenced generally 100. The junction 100 connects two pairs of intersecting lanes 102, and permits forward travel and right and left turns, by virtue of inner branch cables 104 and outer branch

cables 106. Inner branch cables 104 enable a vehicle to turn while crossing a flow of opposing traffic, and outer branch cables 106 enable a vehicle to turn but wherein it is not required to cross a flow of opposing traffic.

As seen, each road unit 10 is connected to a pair of upstream and downstream road units via communications cable 13, while nodal road units 10' (also seen in Fig. 9) connect between a communications cable 13 and an associated branch cable 113. Branch cable 113 has substantially the same construction has cable 13. Each road unit 10 is further connected via segment bus 15 to an associated segment controller 30, it being further seen that each branch cable is similarly connected to a segment branch bus, referenced 15', thereby to form an integral part of a predetermined segment.

The remainder of the arrangement is substantially as described hereinabove in conjunction with Fig. 1. Accordingly, segment controllers 30 are connected to an area controller 26 via an area bus 32; area controllers 26 are connected (not shown) to region controller 20 via region bus 28; and a region controller is ultimately connected, via any intervening system levels, to system controller 18, which, in turn, may be connected to other system controllers via an inter-system link 84 (seen also in Fig. 8). In the present example, link 84 is shown as a radio transmitter.

Typical system data are as follows:

Maximum vehicle velocity	Vmax=200 kph
Minimum length of vehicle	Lmax=3 m
Length of elliptical main communications antenna 56 (Fig. 4B)	Dd=1.5 m
Longitudinal range (Fig. 4B) of capability of transmission and reception of data between the vehicle and a single road unit	Ld=3 m
Possible time period for data communication between the vehicle and a single road unit	Td=Ld/Vmax=54 ms
Diameter of centering antennae 44 (Fig. 4B)	Dc=1.2 m
Longitudinal range of centering capability	Lc=1.2 m
Possible centering duration time with respect to a single road unit	Tc=Lc/Vmax=21.6 m

Typical sizes of transmissions from the vehicle on-board unit 34 to a road unit 10 may be as follows:

Size of a single transmission 'word' from the vehicle on-board unit 34 (Fig. 4A) to a road unit	Ctr=100 bits
Size of an individual vehicle code -	Cid=30 bits
Size of individual journey destinations	AD=24 bits
Report on physical and operational vehicle parameters (dimensions, weight, sensors)	Cs=10 bits
Size of miscellaneous messages	Cm=46 bits

Typical sizes of transmissions from a road unit 10 to a vehicle on-board unit 34 may be as follows:

Size of a transmission 'word' from the road unit to the vehicle	Ltr=100 bits
Size of an individual road unit code -	Lid=30 bits
Size of an instruction to the vehicle	I=30 bits
Size of miscellaneous messages	Lm=40 bits

A minimum transmission rate "Tr" from the vehicle on-board unit to a road unit and vice versa, is represented by the expression Tr>2*(Ctr+Ltr)/Tc and is in the order of 24 Kb/s. In practice this may be several orders of magnitude greater.

The time taken to transmit a message of 100 bits at a minimum transmission rate of approximately 24 Kb/s is represented by the expression Dt=100/Tr and is approximately 4 ms.

It will be appreciated by persons skilled in the art that the above values are typical values only, serving to illustrate possible geometrical and operational parameters that may be desirable in the system of the present invention. The above values are in no way intended to represent operational limitations except where specifically stated as such.

A "normal" communications mode between a vehicle on-board unit 34 and road units 10 is described below in conjunction with an example illustrated in Figs. 9 and 11. A series of three road units 10 is indicated in Fig. 9 as being in Lane 3 of the illustrated highway. The three line units are further designated, for purposes of the present example, by reference numerals I, II and III, wherein the direction of travel of a vehicle (not shown) is taken to be from I towards III, as indicated by an arrow referenced 93. Fig. 11 is a series of graphs depicting communications timing between a vehicle traveling at a velocity

of 200 kph and road units I, II and III. The graphs in Fig. 11 are as follows:

graph (a) shows actual vehicle transmissions,

graphs (b) and (c) show the communications range and actual transmissions, respectively, of road unit I,

graphs (d) and (e) show the communications range and actual transmissions, respectively, of road unit II, and

graphs (f) and (g) show the communications range and actual transmissions, respectively, of road unit III,

In the above-mentioned normal mode, the road units 10 transmit only in response to detection of a transmission from on-board unit 34. When in operation, and in the absence of communications between on-board unit 34 and road units 10, the on-board unit 34 broadcasts "probing" transmissions, typically of about 4 milliseconds in length, every 9 milliseconds. This is seen in graph (a) in Fig. 11, wherein a four millisecond transmission is seen to be transmitted at 0, 9 and 18 milliseconds.

When a transmitting vehicle is located within communication range of a road unit antenna 58 (Fig. 5) or thereover, as illustrated in Fig. 4B, the road unit 10 is operative to detect a probing transmission from the on-board unit 34 so as to be "triggered" thereby. In response to being triggered in this manner, the road unit 10 responds with a broadcast lasting approximately 4 milliseconds, 4 milliseconds after the broadcast of the on-board unit 34 has ended. This is seen in graphs (a) and (c) in which, at 26 milliseconds - 4 milliseconds after the end of the first full transmission

detected by the road unit - the road unit I transmits a 4 millisecond transmission.

If the road unit 10 receives an unidentified transmission (which is not compatible with the structure of the vehicle transmission) it does not respond. This can occur, for instance, when only part of a message is received due to the on-board unit 34 being out of range of the road unit antenna at the start of transmission. This is exemplified in graphs (a) and (b) wherein it is seen that, at the beginning of the second probing transmission from on-board unit 34, at 9 milliseconds, the vehicle has not yet entered the communication range of road unit I. Accordingly, as not all of the 9-13 millisecond pulse is detected by road unit I, it ignores the part-transmission and responds only to the subsequent 18-22 millisecond and 34-38 millisecond transmissions. Similarly, the 50-54 millisecond transmission is only partly received by road unit II, as seen in graph (d), and so a response therefrom - at 67-71 milliseconds (graph (e) - is provided only after detection of the next complete transmission, at 59-63 milliseconds.

As seen in graph (a), when the on-board unit 34 begins receiving the response from the road unit 10, it stops its regular transmissions. This change in transmission pattern is seen in response to the road unit I transmission at 26-30 milliseconds - graph (c), the road unit II transmission at 67-71 milliseconds - graph (e), and the road unit III transmission at 108-112 milliseconds - graph (g).

In the absence of further transmissions from the road

unit 4 milliseconds after the end of a given transmission, the on-board unit 34 resumes its probing transmissions. This resumption to a regular probing transmission pattern is seen in response to the road unit I transmission at 42-46 milliseconds - graph (c), the road unit II transmission at 83-87milliseconds - graph (e), and the road unit III transmission at 124-128 milliseconds - graph (g).

In the above-described 'normal' operational mode, each road unit converses with on-board unit 34 of a particular vehicle twice only. This is due to operational considerations, such as affected by vehicle speed and transmission rate. In certain predetermined cases, however, when the vehicle speeds are very low or when a large amount of information is to be transferred to the vehicle at an increased transmission rate, more than two exchanges between the on-board unit and each road unit may occur. The circumstances in which this happens are determined by controllers at various system levels in accordance with predetermined criteria.

The following points should be noted with respect to the above-described communications protocol:

A. Since the longitudinal communication range (3 meters) of the main antenna 56 of the on-board unit 34 is greater than the distance (2.5 meters) between the road units, there will always be a radio connection between the on-board unit 34 and a road unit, even when the vehicle stops.

B. The above-described procedure is a 'standard' procedure. In addition, the road units may perform various different functions, in accordance with certain situations as

they arise. These situations are determined by the controllers at the various levels, and may include a self-check procedure, a procedure for operation when vehicles are traveling at low speeds, behavior at junctions, in traffic jams, and so on. In accordance with the circumstances and reception of an appropriate instruction from the controllers, the road unit switches from one functional mode to another.

The following are typical types of activity that may be performed while driving:

A. Entering a roadway so as to initiate contact between a vehicle 16 and road units 10.

B. Exiting a roadway so as to terminate contact between a vehicle 16 and road units 10.

C. Traveling in a lane.

D. Passing from one lane to another on a multi-lane road.

E. Exiting from a highway via an exit ramp.

F. Entering a highway via an entry ramp so as to merge with highway traffic.

G. Negotiating a four-way junction of two single lane roads, as shown in Fig. 10.

H. Negotiating traffic jams.

I. Emergency braking, as per the flow chart of Fig. 12.

Some of the above-listed types of driving activity are now described hereinbelow in detail by way of example.

Entering a roadway.

Prior to entering a roadway forming part of the system of the invention (the "roadway"), the on-board unit 34 has no (radio) connection with the system. Driving is therefore manual and carried out according to regular driving principles.

Just before entering the roadway, the driver activates the on-board unit 34 via switch 35 (Fig. 4A). After activation, unit 34 carries out a self-check procedure and notifies the driver of the results of the check. The messages to the driver are provided via visual display 52 and, optionally, via speaker 54. If the system self-check indicates no malfunction the driver is asked to enter a journey destination via data entry device 39.

The driver keys in his destination (the names of all geographical locations covered by the system are in the memory of the on-board data processor 38). The name of the destination is checked by the data processor and appropriate confirmation is given to the driver via display 52 and/or speaker 54.

The on-board unit 34 transmitter starts transmitting the transmission codeword or identification of the vehicle, via the main antenna 56 which is installed beneath the vehicle. Typically, the codeword, which also functions as the above-described probing transmission, is 100 bits long and is of 4 milliseconds duration. The code is transmitted regularly every 9 milliseconds until 'contact' is made with the system, as described above in conjunction with Fig. 11.

The driver drives the vehicle onto the road manually, with the center of the vehicle over the communications cable 13. As soon as a road unit 10 detects receives the probing

transmission so as to be triggered thereby, it responds immediately with a confirmation broadcast. From this moment, until the vehicle either leaves a roadway encompassed by the system of the invention, or unless the driver deactivates on-board unit 34 via switch 35, the system takes over driving of the vehicle.

The road unit 10 first encountered by the vehicle transfers the driver's destination request to the segment controller 30 (Fig. 1). If the destination is within the segment whereat the vehicle is located at the time of the request ("the vehicle segment"), the request is processed directly by the segment controller 30, which subsequently transmits an appropriate message via appropriate road units 10, back to the on-board unit 34.

If the destination is not within the vehicle segment, the segment controller 30 transmits the destination request, via an area bus 32, to an area controller 26. If the destination is within the vehicle area, the journey destination is processed by the area controller 26. If the journey destination is not within the vehicle area, the journey destination data is transmitted to controllers at successively higher levels in the system hierarchy, until the appropriate level of hierarchy is reached. Subsequently, output data corresponding to the journey destination is transmitted downward through the various system levels, until it is received by the on-board main antenna 56.

Accordingly, at the end of the processing process, the driver receives confirmation. The confirmation includes

information regarding the selected route, the expected duration of the journey and other messages as necessary. The driver may either confirm, cancel or request changes in the route via data entry device 39.

After confirmation by the driver of a particular journey route, the controllers at the various levels transmit operational instructions to road units located along the route. These instructions may include the vehicle code, other vehicle particulars, estimated time of arrival at each road unit, navigational details, and speed of travel, as well as miscellaneous instructions to the on-board unit 34 and messages to the driver.

The road unit 10 in the immediate vicinity of the vehicle then initiates transmittal of operational instructions to the on-board unit 34, and the vehicle which commences automatic travel.

Exiting a roadway.

Prior to reaching a predetermined exit location from the roadway, from where manual driving will be required, the driver receives a warning message via display 52 and/or speaker 54 of the impending exit. The on-board unit 34 subsequently reduces the driving speed of the vehicle to manual driving level.

As the vehicle is above the last road unit prior to exit, they exchange a final transmission, confirming the status of the vehicle upon exit, and the vehicle then goes over to manual control by the driver. The status of the vehicle upon exit is then transmitted to the segment controller 30, and from there

to higher levels in the system, as required.

Traveling in a lane

As the vehicle travels along a lane portion of a roadway, as seen, for example, in Figs. 3 and 9, the route particulars of the vehicle are transferred from the controllers at the various levels to the road units 10. Accordingly, each road unit 10 stores in its memory (data processor 62) the data of each vehicle expected, in arrival order (FIFO). The size of the road unit memory determines the number of vehicles it is possible to store. Vehicle journey data may be updated via the segment controller 30 (Figs. 1 and 6) when necessary. The data may include, inter alia, the vehicle identification or codeword, estimated time of arrival, average expected journey speed, navigational instructions, as well as any further instructions to the on-board unit 34 and miscellaneous messages to be transmitted to the driver.

As described above in conjunction with Fig. 11, the road units 10 are in a standby mode until a valid transmission (transmission structure, coding method, and so on) is received from a vehicle. Once a valid transmission from a vehicle on-board unit 34 is received, the receiving road unit checks data received from the on-board unit 34, including the vehicle codeword or identification number, vehicle data, and miscellaneous messages.

If the identification number is invalid, unclear or not as expected, the road unit waits for the second transmission from the on-board unit 34. If the identification number is incorrect in the second transmission as well, the road unit enters an emergency braking procedure. This is described below in

conjunction with Fig. 12.

If the identification number is valid, clear and correct, the road unit data processor 62 processes the messages. These messages may include a request for change in route, a request for specific geographic, commercial or any other general type of information, transfer of messages to stationary stations such as a private or business address. The messages are transferred for action to the segment controller 30, which either processes them and responds directly, or transmits the messages to a higher system level.

A further function of the road units is to check if the actual vehicle arrival time is as expected. If not, data processor 62 calculates a required change in speed, and instructs on-board data processor 38 (Fig. 4A) accordingly, which then acts to change the speed via control interface 40. If the difference between actual and required speed is greater than a value predetermined in accordance with criteria such as, the speed of travel in the segment, planned distances between vehicles, safety conditions in the segment, the emergency braking procedure may be initiated.

Subsequently, the road unit transmits a response to the vehicle on-board unit 34. The response may include instructions generated by the road unit, such as, change of speed, emergency braking and the like, and instructions and messages from the segment controller, such as, average journey speed so far, navigational instructions, and miscellaneous messages.

In addition to the transmissions from a given road unit

to a given vehicle on-board unit, the road unit also transmits a message via serial link 14 to the next (downstream) road unit in the direction of travel. The message includes, inter alia, the identification number of the vehicle next scheduled to reach it and how long it will take to arrive or "instantaneous arrival time." The instantaneous arrival time is based on the actual speed of the vehicle as it passes the transmitting road unit and any speed change or navigational instructions, and is thus different from the estimated time of arrival according to the travel plan, as transmitted to the receiving road unit by the segment controller.

As a further safety precaution, the downstream road unit constantly checks if the vehicle which has just left the upstream road unit, and which should reach the downstream road unit in a given time, has indeed arrived as expected. If the vehicle is found not to have arrived within the expected time period, the road unit enters the emergency braking procedure.

The upstream road unit stores various predetermined types of data of the vehicle which has passed in its memory. For this purpose it can use the same place in its memory on which were written the data it transmitted to the on-board unit 34 and which it no longer needs.

Each road unit transfers messages to its segment controller 30 via parallel communications bus 15 (Fig. 1) in accordance with a predetermined procedure. The messages include, inter alia, a report on the passage of vehicles and messages associated with each vehicle; information concerning special occurrences, such as, emergency braking; service requests of the

road unit itself, for instance, a request for memory update; messages concerning faults in the line; and so on.

Reference is now made to Fig. 12, which is a flow chart diagram of an emergency braking procedure, in accordance with an embodiment of the invention.

Emergency braking of one or more vehicles may be initiated by the system, in response to a plurality of predetermined conditions listed below; by one or more road units 10 as a reflexive response to various predetermined situations, for example, if a vehicle does not reach a specific road unit within an expected time period, or if the vehicle is found to be malfunctioning; or by the driver. Typically, if the driver wishes to stop, entry of an appropriate instruction to on-board unit 34, either via data entry device 39 or by depressing the vehicle brake pedal, for example, will cause the system to enter an emergency braking procedure.

Conditions in response to which the system initiates emergency braking include the following:

a deviation from the journey schedule greater than permitted,

a deviation from the order of travel of a group of vehicles,

reports by drivers on emergency situations.

A typical emergency braking procedure is as follows:

1. A road unit "X" in communication range with a vehicle to be stopped transmits (block 110, line 112) an instruction to the vehicle on-board unit 34 to reduce the velocity V of the

vehicle to V=0. The vehicle to be stopped is denoted as vehicle "Vs" in Fig. 12.

2. Road unit X transmits (block 110, line 114) a message via serial link 14 to an adjacent downstream road unit "X+1" - if road unit X is an upstream nodal unit (i.e. branching downstream of road unit X) then the message is transmitted to both downstream road units. The message includes an instruction to stop the vehicle about to reach the downstream unit, together with the identification number of the vehicle.

As stopping does not occur instantaneously, unit X+1 informs (block 116) the subsequent downstream road unit "X+2" to continue stopping the vehicle. In this way, successive downstream road units continue to inform those ahead of them to stop the specified vehicle until it is brought to a complete halt. If there is another vehicle, which has no connection with the emergency braking, downstream of the vehicle for which the stopping procedure was initiated, it will continue to travel normally.

3. Road unit X transmits (block 110, line 118) a message along serial link 14 to the road unit "X-1" immediately upstream thereof - if road unit X is a downstream nodal unit (i.e. branching upstream of road unit X) the message is transmitted to both adjacent upstream road units.

The message includes the following instructions:

a. go over to emergency braking procedure;

b. my safety range is distance L, wherein L is measured in road units and equals Car Length + Braking Distance, and wherein Braking Distance is determined by

the system in accordance with the safety conditions of the roadway where the braking is being performed; and

c. the maximum permitted speed of travel over me (i.e. unit X) is V which, at initiation of the braking procedure, equals 0.

4. The road unit X-1 - upstream of road unit X - then performs the following calculations:

a. if there is a new vehicle (different from the previous one) in communication range of unit X-1 (block 120), then L = New Car length + Braking Distance (block 122);

if there is no new vehicle above unit X-1 then L = L-1 until L reaches zero (block 124).

If L>0 then V remains unaltered (block 128);

if L = 0 (block 130), then V = V + dV (block 132), wherein dV is a predetermined speed increment set in advance by the controllers according to safety considerations on the particular road - V cannot be greater than Vmax defined for the particular road according to the above considerations.

5. Road unit X-1 transmits (block 134) the following:

a. a message to the vehicle immediately above, informing it of its current speed; and

b. a message to the immediately upstream road unit "X-2", as follows:

execute emergency braking procedure,

my safety range is L (according to calculations above),

the permitted maximum speed of travel in my vicinity V (as

defined above).

In this way, if there is a gap between the first vehicle (which is stopping) and those behind it, the force of the stopping will be reduced gradually. This is indicated in the graphical representation of target speed versus distance (in terms of road units) shown at block 136 in Fig. 12. It is seen that speed is reduced gradually as successive upstream vehicles travel downstream toward the road unit X that initiated the braking procedure.

6. The third and subsequent upstream road units X-2, ..., X-n, operate (block 138) in a manner similar to that described for road unit X-1.

It will be appreciated by persons skilled in the art that the scope of the present invention is not limited by what has been shown and described hereinabove, merely by way of example. Rather, the scope of the invention is defined solely by the claims, which follow.

CLAIMS

1. A transport system which comprises:

a communications network which comprises:

a transport control unit; and

a plurality of road units arranged in series along a vehicle travel route, each road unit being adapted for communication with said transport control unit so as to exchange data therewith, and being further adapted for direct communication with at least two road units positioned adjacent thereto; and

at least one vehicle having an on-board control and data exchange unit which includes:

transceiver means for communicating with each of said plurality of road units in series while traveling therepast;

data processing means connected to said transceiver means; and

control means, connected to said data processing means for selectably controlling and sensing any of a predetermined plurality of vehicle operating functions in response to signals received by said transceiver means from said road units,

wherein said road units are arranged along a predetermined path along said travel route and are operative, in conjunction with said on-board unit, to enable a predetermined positioning of said vehicle relative to said predetermined path.

2. A system according to claim 1, and also including end road units similar to said plurality of road units, but adapted for communication with a single adjacent road unit only.

3. A system according to claim 1, and wherein said on-board control and data exchange unit and each said road unit cooperate together so as to enable said predetermined positioning of said vehicle.

4. A system according to claim 3, and wherein said on-board control and data exchange unit and each said road unit are adapted for selectable operation in either a first, fully automatic mode or in a second, non-fully automatic man-in-the-loop mode.

5. A system according to claim 1, and wherein said on-board control and data exchange unit also includes first antenna means mounted in a predetermined position on said vehicle and associated with said data processing means, and wherein each said road unit includes second antenna means, wherein a predetermined one of said first and second antenna means comprises a pair of antennae arranged in a predetermined orientation, there also being provided comparator means, associated with said pair of antennae, for providing an output indication of the position of said vehicle relative to said predetermined path.

6. A system according to claim 5, and wherein said pair of antennae and said comparator means form part of said on-board control and data exchange means on said vehicle, and are connected to said data processing means thereof.

7. A system according to claim 5, and wherein said pair of antennae and said comparator means are adapted to provide signals to said data processing means indicating the degree of alignment of said vehicle along said predetermined path.

8. A transport system according to claim 7, and wherein said on-board control and data exchange unit also comprises a main communications antenna connected to said transceiver means, adapted to receive and transmit data messages between said data processing unit and said road units.

9. A system according to claim 1, and wherein said transceiver means is operative to provide signal outputs to said road units, said signal outputs comprising messages of a type selected from the group which consists of:

vehicle identification data;

messages indicative of vehicle operation parameters;

messages indicative of driver-vehicle inputs; and

driver-initiated data enquiry messages.

10. A system according to claim 9, and wherein said road units are operative to transmit signals corresponding to said

signal outputs from said transceiver means to said transport control unit, and said data processing means of said on-board control and data exchange unit comprises first data processing means,

and wherein said transport control unit comprises:

communication means for selectably communicating with each of said plurality of road units in response to reception of input signals therefrom; and

second data processing means, connected to said communication means, for processing input data corresponding to said input signals, and for providing output data for transmission by said communication means to said road units in the form of output signals.

11. A system according to claim 10, and wherein said system further comprises:

an additional plurality of transport control units similar to said transport control unit, and

an additional transport control level operative to control said plurality of transport control units, wherein each said additional level has at least one super transport control unit which comprises:

communication means for selectably communicating with each of said plurality of transport control units in response to reception of input signals therefrom; and

third data processing means, connected to said communication means of said super transport control unit, for processing input data corresponding to said input signals, and

for providing output data for transmission by said communication means to said transport control units in the form of output signals.

12. A system according to claim 11, and wherein said system further comprises a plurality of hierarchical control levels, each having a plurality of transport control units arranged to control vehicles in a predetermined geographical zone, each said level being operative to control a control level immediately therebeneath in the hierarchy, each said hierarchical control level comprising:

at least one communication means for selectably communicating with a control level immediately therebenath in response to reception of input signals therefrom; and

at least one data processing means, connected to each said communication means of said hierarchical control level, for processing input data corresponding to said input signals, and for providing output data for transmission by said communication means to the control level immediately therebeneath in the form of output signals.

13. A system according to claim 12, and wherein each said transport control unit is operative to receive data messages originating from the on-board unit of a vehicle travelling in the geographical zone of that transport control unit, and wherein, if the data message relates to a geographical zone other than that of that transport control unit, said communications means of

said transport control unit is also operative to transfer the data message to the transport control unit of the level immediately above.

14. A system according to claim 10, and wherein each of said road units is operative, in response to detection of passage of said vehicle, to transmit an output signal to at least an immediately adjacent downstream road unit, indicating travel of said vehicle toward said downstream unit.

15. A system according to claim 10, and wherein said predetermined path also includes forks which diverge from nodal road units, each said nodal road unit being arranged in generally equidistant relationship from a pair of immediately adjacent road units located downstream along divergent paths, and wherein each said nodal road unit is operative, in response to detection of passage of said vehicle, to transmit an output signal to at least said pair of immediately adjacent downstream road units, indicating travel of said vehicle towards a preselected one of said pair.

16. A system according to claim 10, and wherein said transport control unit is operative to operate said road units so as to transmit navigational instructions to said on-board unit of said vehicle, in accordance with a preselected travel path thereof.

17. A system according to claim 10, and wherein each of said road units is operative, in response to at least one of vehicle operation parameter values or driver-vehicle input values outside of a predetermined range, to automatically transmit an emergency indication directly to at least one adjacent road unit, said at least one adjacent unit being operative, in response to receipt of said emergency indication, to provide a control signal to said transceiver means of said on-board control and data exchange unit in accordance with said emergency indication.

18. A system according to claim 14, and wherein said road units to which the emergency indication is transmitted are operative also to provide control signals to said transceiver means of said on-board control and data exchange unit of a plurality of vehicles whose travel data are affected by the vehicle whose parameter values or input values are determined to be outside the predetermined range.

19. A system according to claim 18, and wherein said at least one adjacent road unit is operative, in response to reception of the emergency indication, to transmit a velocity control signal to said vehicle on-board unit.

20. A system according to claim 18, and wherein a plurality of upstream road units and a plurality of downstream road units, relative to said automatically transmitting road unit, are operative to activate immediately adjacent road units so as to transmit velocity control signals to a plurality of on-board

units located on said plurality of vehicles whose travel data are affected by the vehicle whose parameter values or input values are determined to be outside the predetermined range.

21. A system according to claim 1, and wherein said transceiver means of said on-board control and data exchange unit is operative to provide intermittent probing signals as said vehicle travels along said travel route, and wherein said road units comprise means for detecting said probing signals and for triggering said road units in response thereto.

22. A transport system which comprises:

a network of intersecting travel routes;

a plurality of vehicles each adapted for travel along any selected travel route; and

a control system for controlling travel of each of said plurality of vehicles simultaneously, wherein travel parameters of each said vehicle are determined in accordance with travel parameters of other of said vehicles.

23. A system according to claim 22, and wherein said control system comprises a communications network which includes:

a plurality of transport control units, each adapted to control travel of said plurality of vehicles along travel routes in a predetermined geographical zone; and

a plurality of road units arranged in series along said intersecting travel routes, each road unit being adapted for

communication with said transport control unit so as to exchange data therewith, and being further adapted for direct communication with at least two road units positioned adjacent thereto, and wherein

each said vehicle has an on-board control and data exchange unit which includes:

transceiver means for communicating with each of said plurality of road units in series while traveling therepast;

data processing means connected to said transceiver means; and

control means, connected to said data processing means for selectably controlling and sensing any of a predetermined plurality of vehicle operating functions in response to signals received by said transceiver means from said road units,

wherein said road units are arranged along predetermined paths along said intersecting travel routes and are operative, in conjunction with said on-board unit of each said vehicle, to enable a predetermined positioning thereof relative to said predetermined path.

24. A system according to claim 23, and also including end road units similar to said plurality of road units, but adapted for communication with a single adjacent road unit only.

25. A system according to claim 23, and wherein said on-board control and data exchange unit and each said road unit cooperate together so as to enable said predetermined positioning of said vehicle.

26. A system according to claim 25, and wherein said on-board control and data exchange unit and each said road unit are adapted for selectable operation in either a first, fully automatic mode or in a second, non-fully automatic man-in-the-loop mode.

27. A system according to claim 23, and wherein said on-board control and data exchange unit also includes first antenna means mounted in a predetermined position on said vehicle and associated with said data processing means, and wherein each said road unit includes second antenna means, wherein a predetermined one of said first and second antenna means comprises a pair of antennae arranged in a predetermined orientation, there also being provided comparator means, associated with said pair of antennae, for providing an output indication of the position of said vehicle relative to said predetermined path.

28. A system according to claim 27, and wherein said pair of antennae and said comparator means form part of said on-board control and data exchange means on said vehicle, and are connected to said data processing means thereof.

29. A system according to claim 27, and wherein said pair of antennae and said comparator means are adapted to provide signals to said data processing means indicating the degree of alignment of said vehicle along said predetermined path.

30. A transport system according to claim 29, and wherein said on-board control and data exchange unit also comprises a main communications antenna connected to said transceiver means, adapted to receive and transmit data messages between said data processing unit and said road units.

31. A system according to claim 23, and wherein said transceiver means is operative to provide signal outputs to said road units, said signal outputs comprising messages of a type selected from the group which consists of:

vehicle identification data;

messages indicative of vehicle operation parameters;

messages indicative of driver-vehicle inputs; and

driver-initiated data enquiry messages.

32. A system according to claim 31, and wherein said road units are operative to transmit signals corresponding to said signal outputs from said transceiver means to said transport control unit, and said data processing means of said on-board control and data exchange unit comprises first data processing means,

and wherein said transport control unit comprises:

communication means for selectably communicating with each of said plurality of road units in response to reception of input signals therefrom; and

second data processing means, connected to said communication means, for processing input data corresponding to

said input signals, and for providing output data for transmission by said communication means to said road units in the form of output signals.

33. A system according to claim 32, and wherein said system further comprises an additional transport control level operative to control said plurality of transport control units, wherein each said additional level has at least one super control unit which comprises:

communication means for selectably communicating with each of said plurality of transport control units in response to reception of input signals therefrom; and

third data processing means, connected to said communication means of said super control unit, for processing input data corresponding to said input signals, and for providing output data for transmission by said communication means to said transport control units in the form of output signals.

34. A system according to claim 33, and wherein said system further comprises a plurality of hierarchical control levels, each having a plurality of transport control units arranged to control vehicles in a predetermined geographical zone, each said level being operative to control a control level immediately therebeneath in the hierarchy, each said hierarchical control level comprising:

at least one communication means for selectably communicating with a control level immediately therebenath in

response to reception of input signals therefrom; and

at least one data processing means, connected to each said communication means of said hierarchical control level, for processing input data corresponding to said input signals, and for providing output data for transmission by said communication means to the control level immediately therebeneath in the form of output signals.

35. A system according to claim 34, and wherein each said transport control unit is operative to receive data messages originating from the on-board unit of a vehicle travelling in the geographical zone of that transport control unit, and wherein, if the data message relates to a geographical zone other than that of that transport control unit, said communications means of said transport control unit is also operative to transfer the data message to the transport control unit of the level immediately above.

36. A system according to claim 32, and wherein each of said road units is operative, in response to detection of passage of said vehicle, to transmit an output signal to at least an immediately adjacent downstream road unit, indicating travel of said vehicle toward said downstream unit.

37. A system according to claim 32, and wherein said predetermined path also includes forks which diverge from nodal road units, each said nodal road unit being arranged in generally equidistant relationship from a pair of immediately adjacent road

units located downstream along divergent paths, and wherein each said nodal road unit is operative, in response to detection of passage of said vehicle, to transmit an output signal to at least said pair of immediately adjacent downstream road units, indicating travel of said vehicle towards a preselected one of said pair.

38. A system according to claim 32, and wherein said transport control units are operative to operate said road units so as to transmit navigational instructions to said on-board unit of said vehicle, in accordance with a preselected travel path thereof.

39. A system according to claim 32, and wherein each of said road units is operative, in response to at least one of vehicle operation parameter values or driver-vehicle input values outside of a predetermined range, to automatically transmit an emergency indication directly to at least one adjacent road unit, said at least one adjacent unit being operative, in response to receipt of said emergency indication, to provide a control signal to said transceiver means of said on-board control and data exchange unit in accordance with said emergency indication.

40. A system according to claim 39, and wherein said road units to which the emergency indication is transmitted are operative also to provide control signals to said transceiver means of said on-board control and data exchange unit of a

plurality of said vehicles whose travel data are affected by the vehicle whose parameter values or input values are determined to be outside the predetermined range.

41. A system according to claim 40, and wherein said at least one adjacent road unit is operative, in response to reception of the emergency indication, to transmit a velocity control signal to said vehicle on-board unit.

42. A system according to claim 40, and wherein a plurality of upstream road units and a plurality of downstream road units, relative to said automatically transmitting road unit, are operative to activate immediately adjacent road units so as to transmit velocity control signals to a plurality of on-board units located on said plurality of vehicles whose travel data are affected by the vehicle whose parameter values or input values are determined to be outside the predetermined range.

43. A system according to claim 22, and wherein said transceiver means of said on-board control and data exchange unit is operative to provide intermittent probing signals as said vehicle travels along a travel route, and wherein said road units comprise means for detecting said probing signals and for triggering said road units in response thereto.

44. A system according to any of claims 1-43 and substantially as shown and described hereinabove in conjunction with any of Figs. 1-12.

45. A system according to any of claims 1-43 and substantially as shown in any of Figs. 1-12.

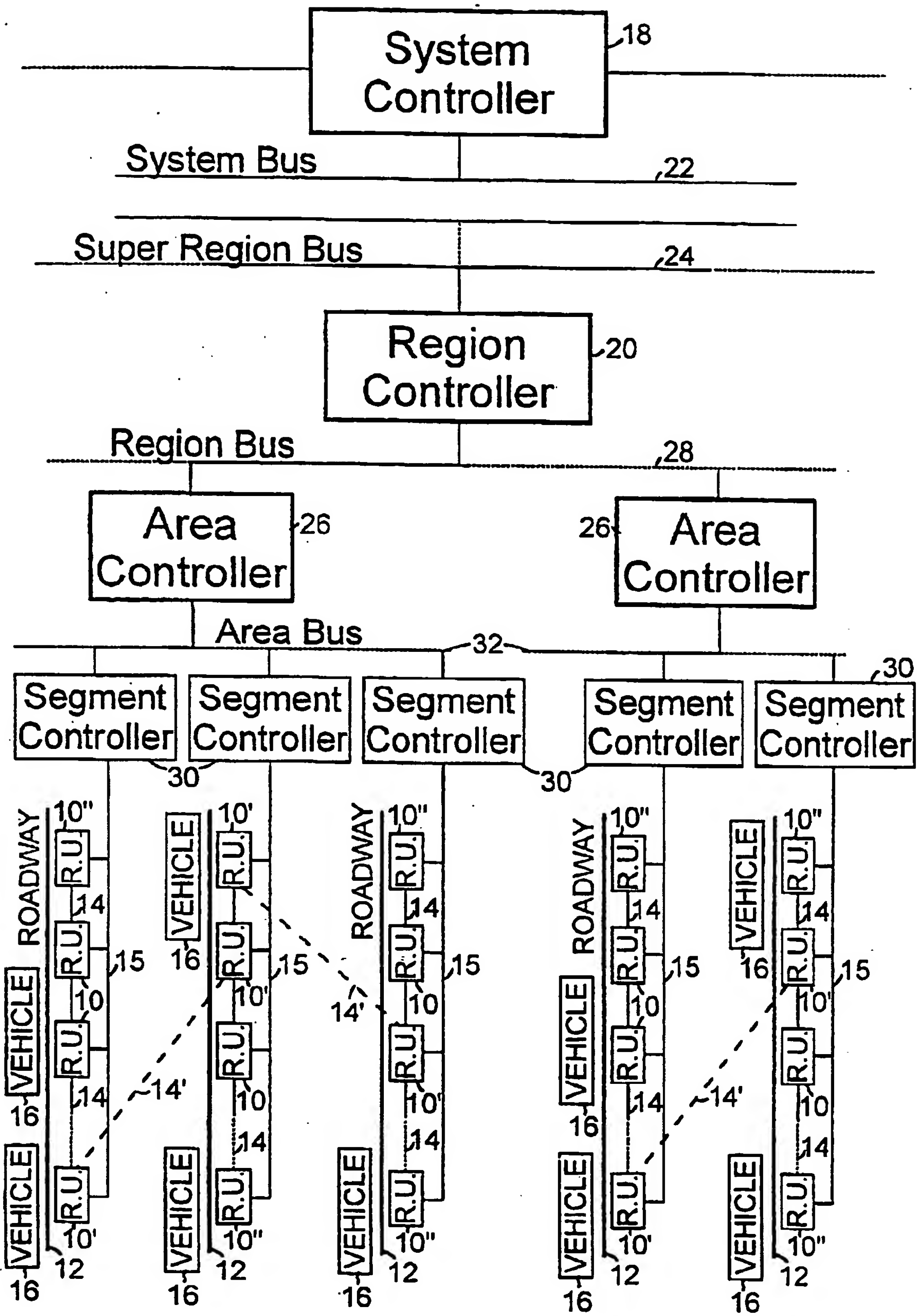
System Controller
18
System Bus
22
Super Region Bus
24
Region Controller
20
Region Bus
28
Area Controller
26
Area Controller
26
Area Bus
32
Segment Controller
Segment Controller
Segment Controller
Segment Controller
Segment Controller
30
ROADWAY
VEHICLE
R.U.
10"
10'
10
14
14'
15
16
12

Fig. 1

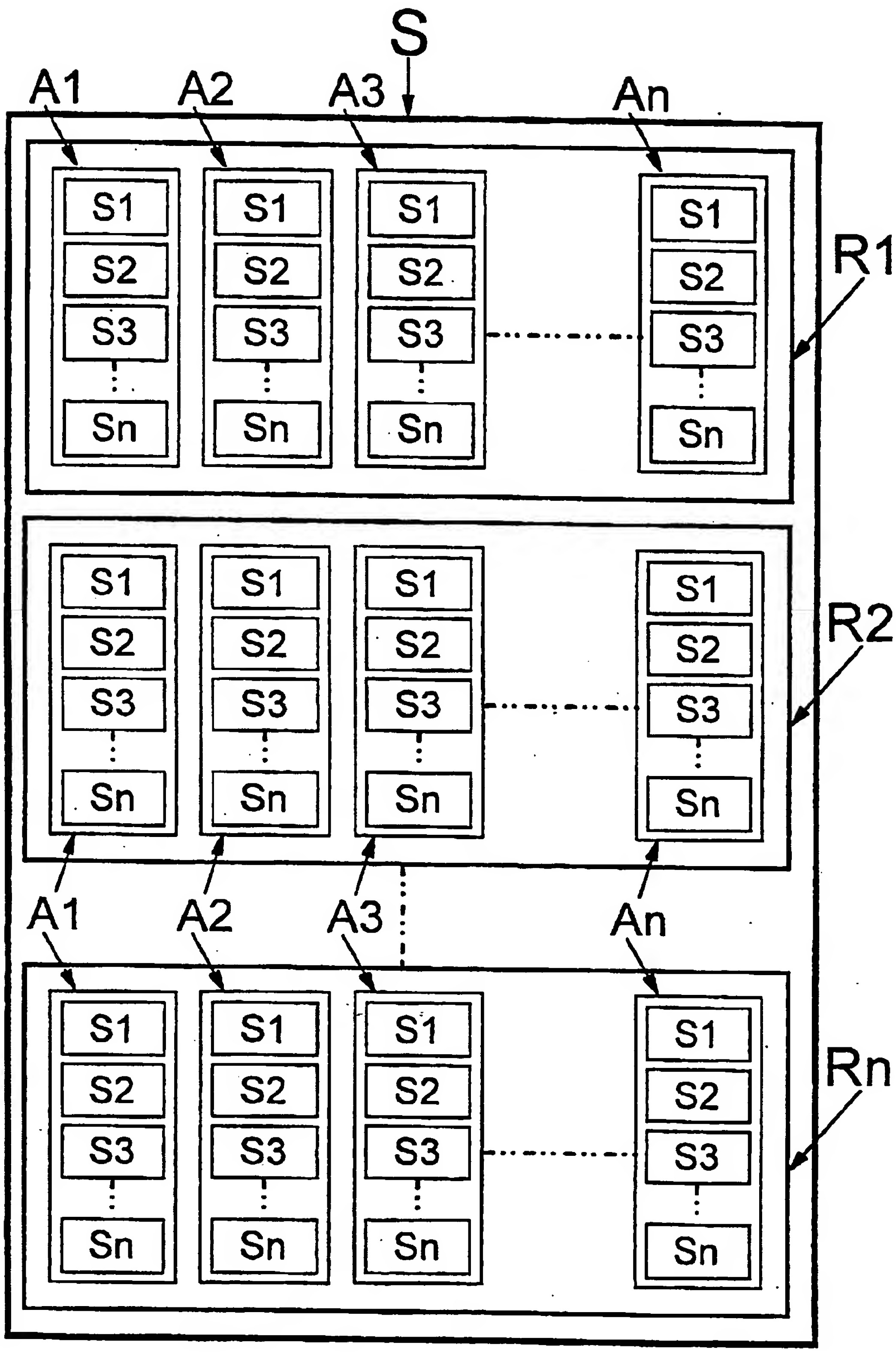

Fig. 2

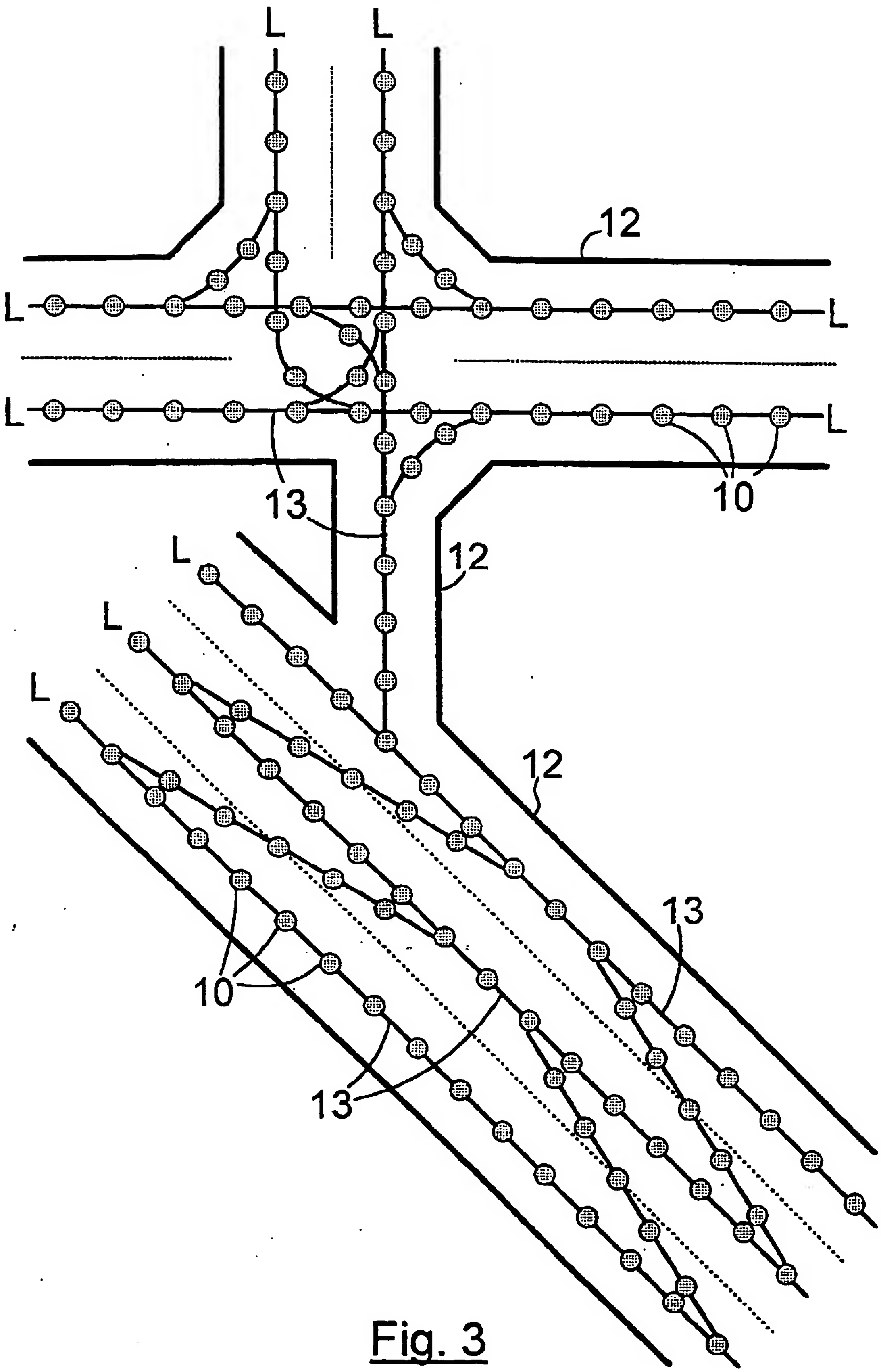

Fig. 3

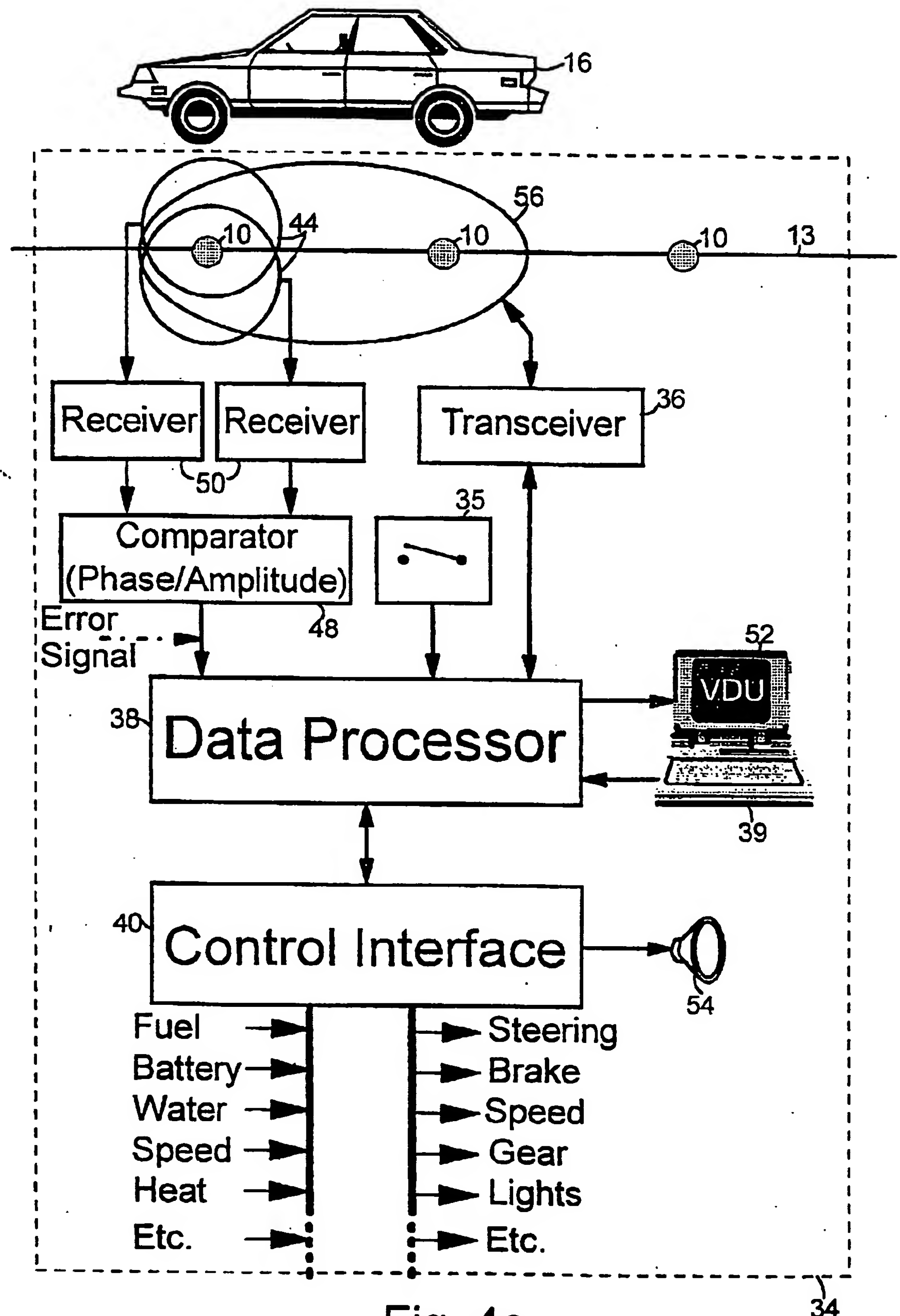
16
56
10
44
10
10
13
Receiver
Receiver
Transceiver
36
50
35
Comparator
(Phase/Amplitude)
Error
Signal
48
52
VDU
38
Data Processor
39
40
Control Interface
54
Fuel
Battery
Water
Speed
Heat
Etc.
Steering
Brake
Speed
Gear
Lights
Etc.
34

Fig. 4a

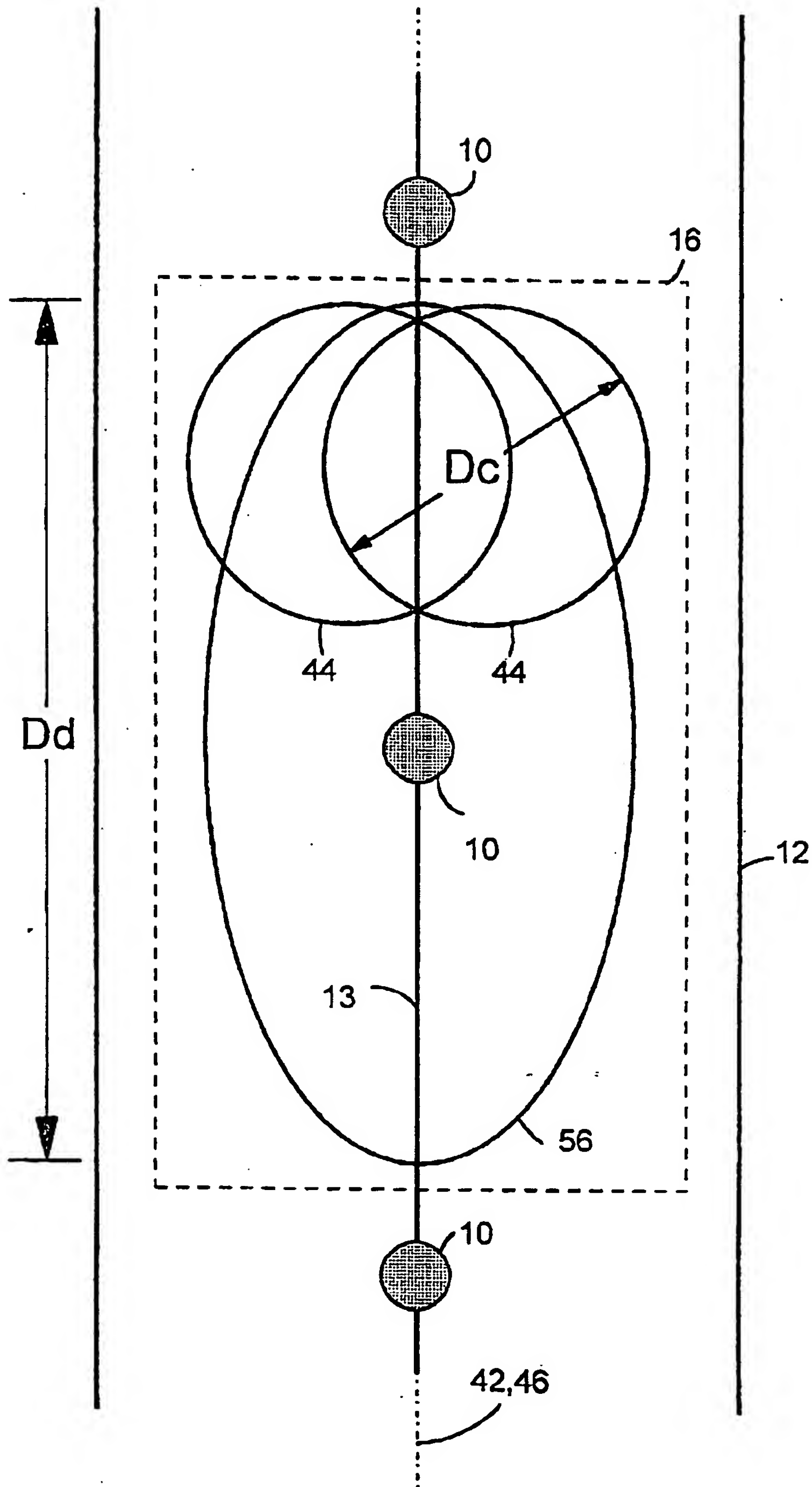

Fig. 4b

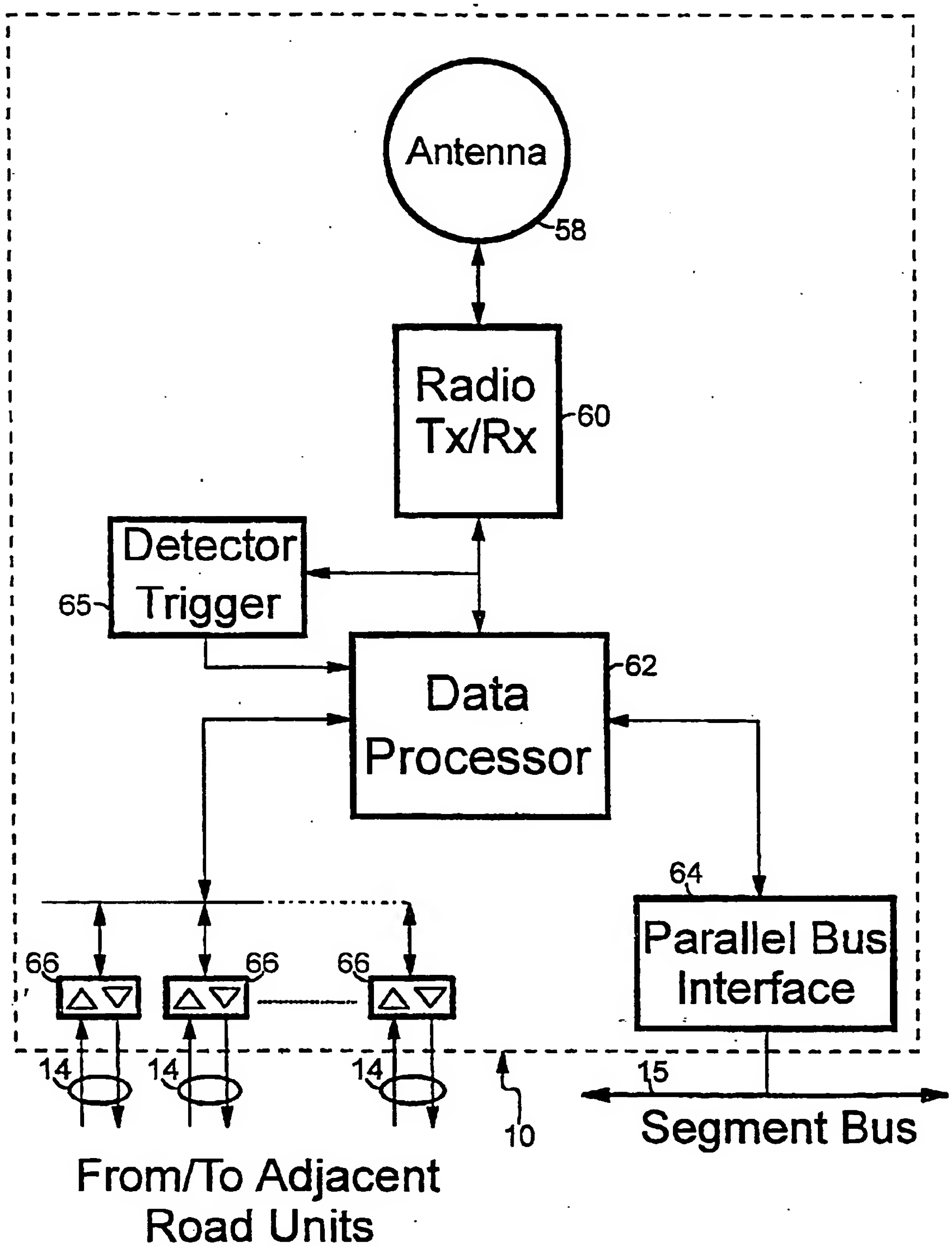
Antenna
58
Radio Tx/Rx
60
Detector Trigger
65
Data Processor
62
64
Parallel Bus Interface
66
66
66
14
14
14
10
15
Segment Bus
From/To Adjacent Road Units

Fig. 5

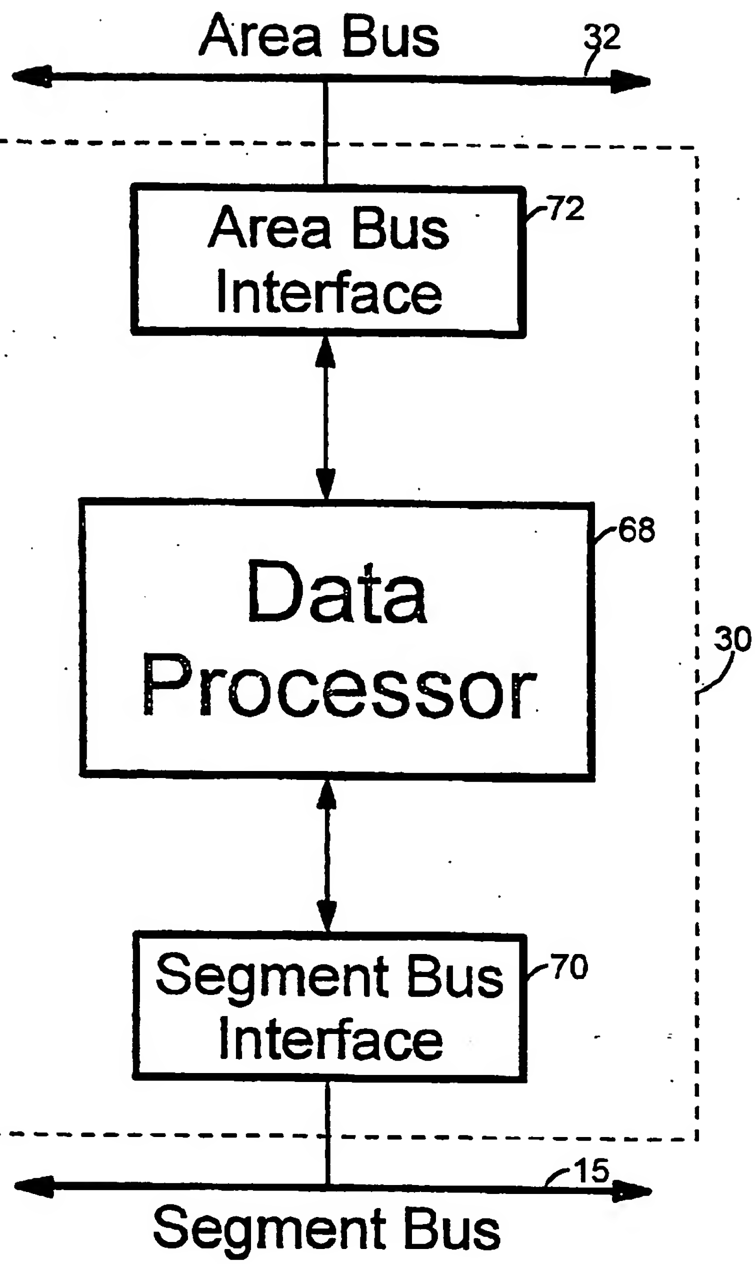
Area Bus
32
Area Bus Interface
72
Data Processor
68
30
Segment Bus Interface
70
15
Segment Bus

Fig. 6a

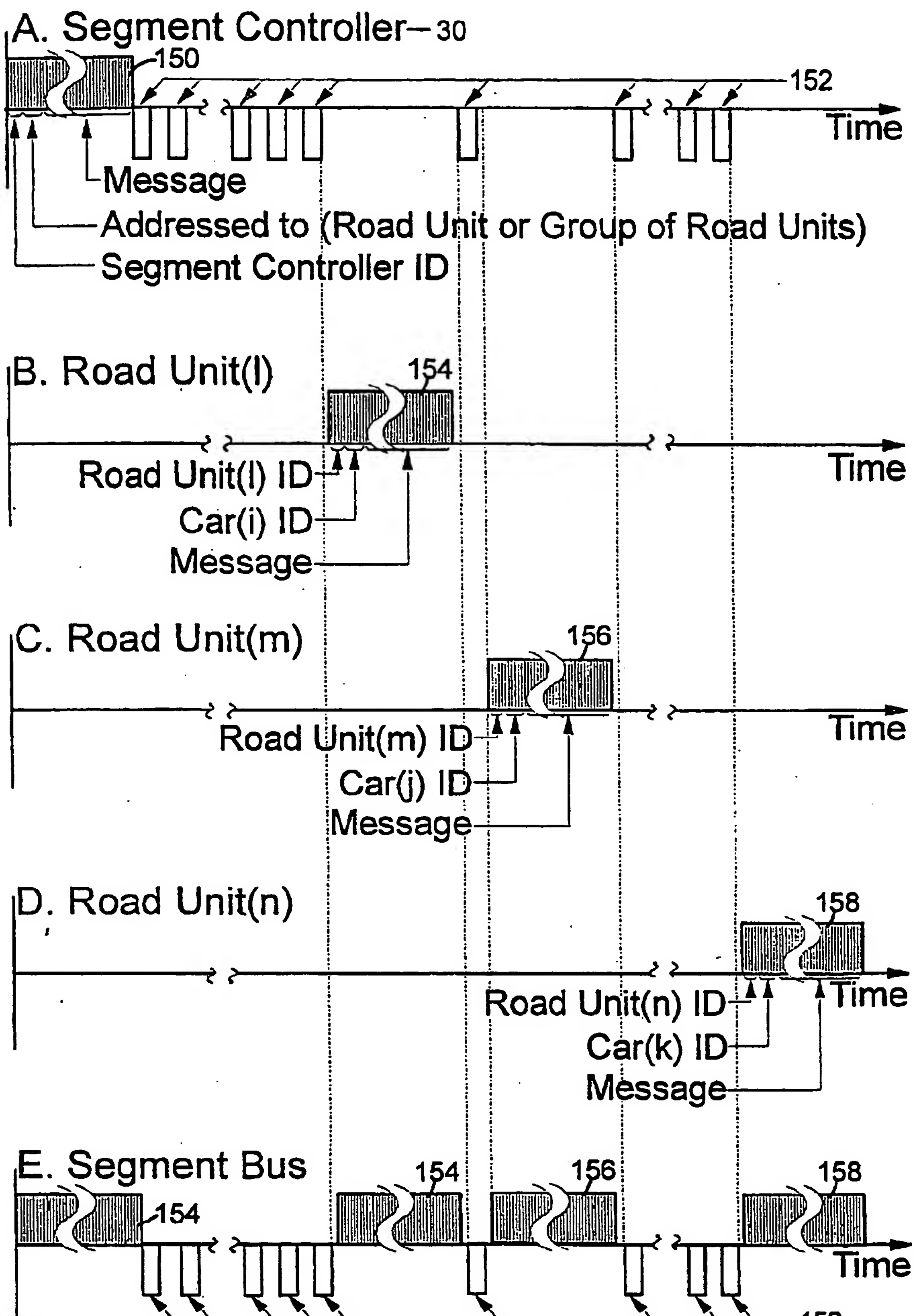
A. Segment Controller–30
150
152
Time
Message
Addressed to (Road Unit or Group of Road Units)
Segment Controller ID
B. Road Unit(l)
154
Time
Road Unit(l) ID
Car(i) ID
Message
C. Road Unit(m)
156
Time
Road Unit(m) ID
Car(j) ID
Message
D. Road Unit(n)
158
Time
Road Unit(n) ID
Car(k) ID
Message
E. Segment Bus
154
154
156
158
Time
152

Fig. 6b

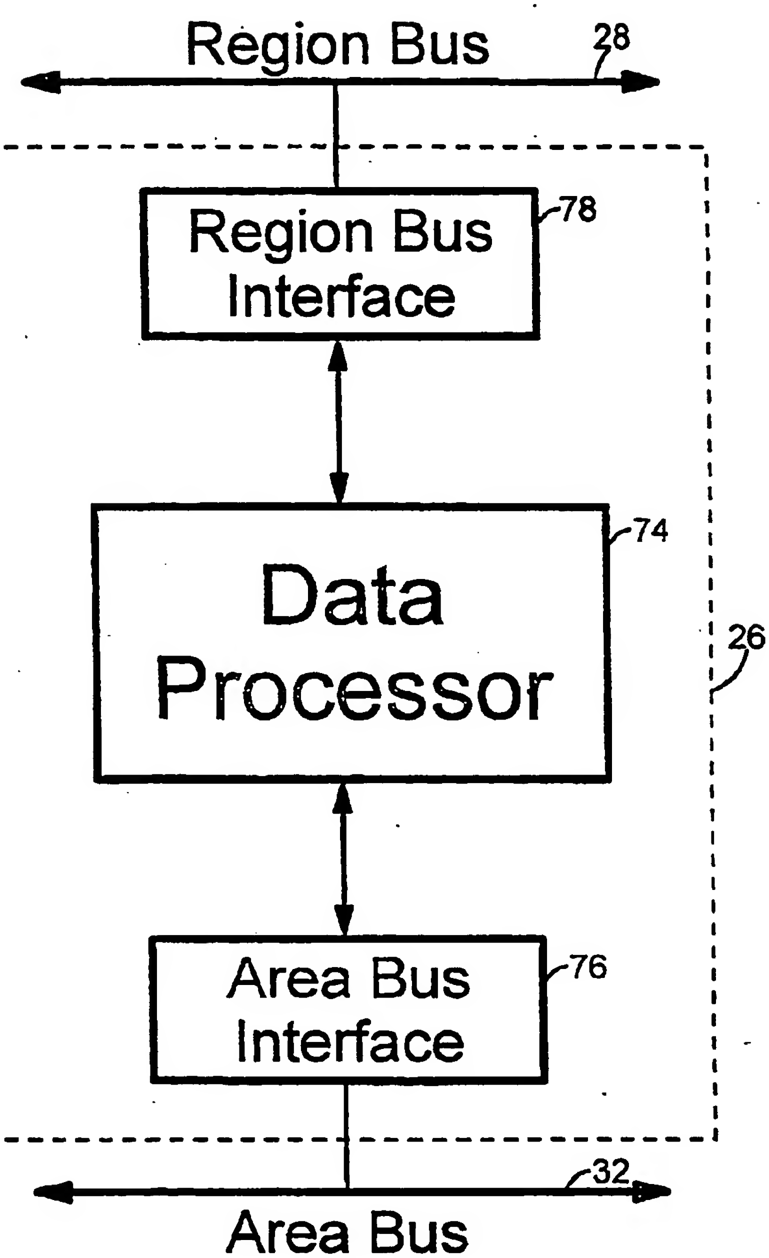
Region Bus
28
Region Bus Interface
78
Data Processor
74
26
Area Bus Interface
76
32
Area Bus

Fig. 7

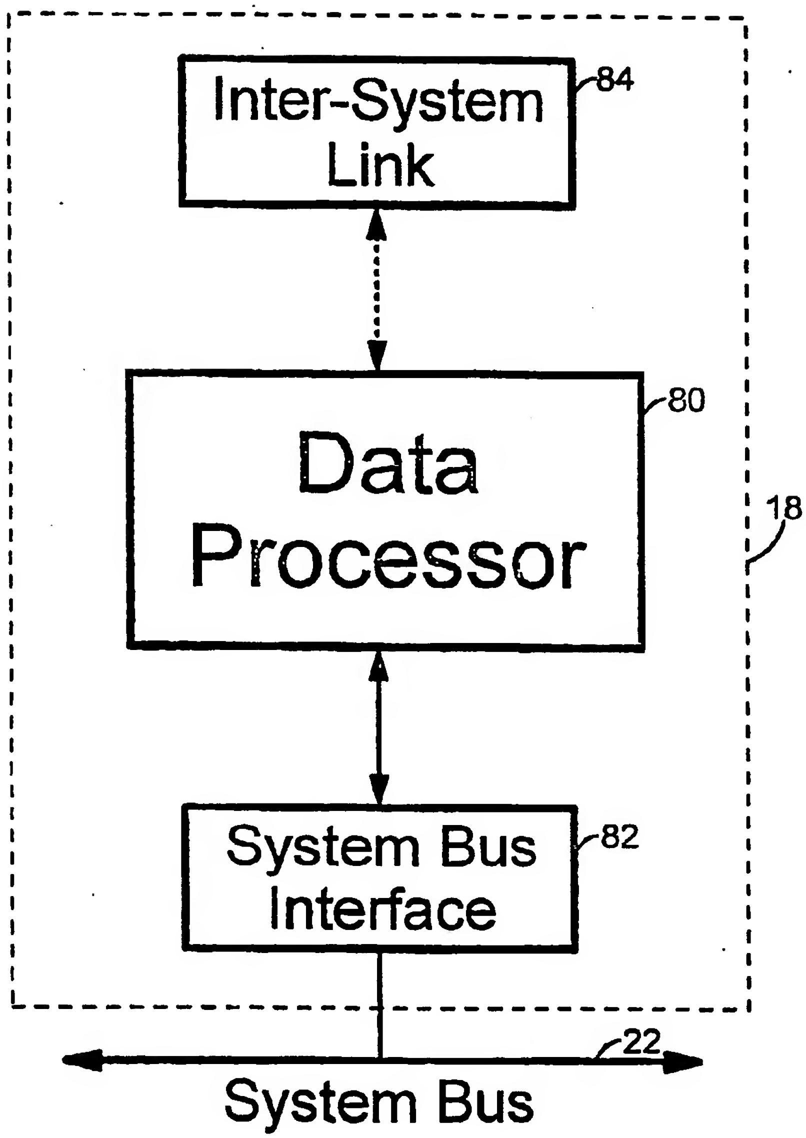
Inter-System Link
84
Data Processor
80
18
System Bus Interface
82
22
System Bus

Fig. 8

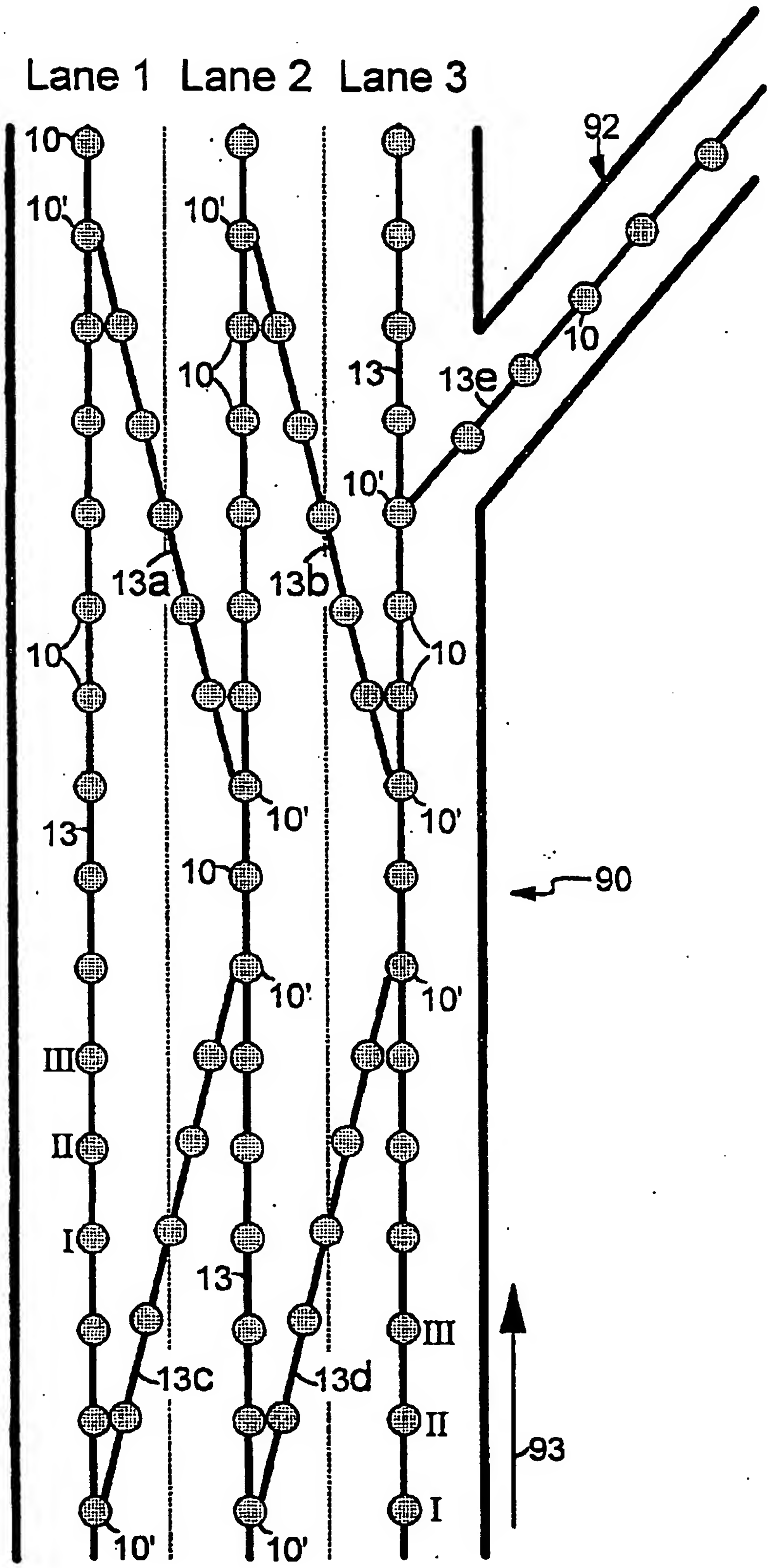
Lane 1
Lane 2
Lane 3
10
10'
10
13
13a
13b
13c
13d
13e
I
II
III
90
92
93

Fig. 9

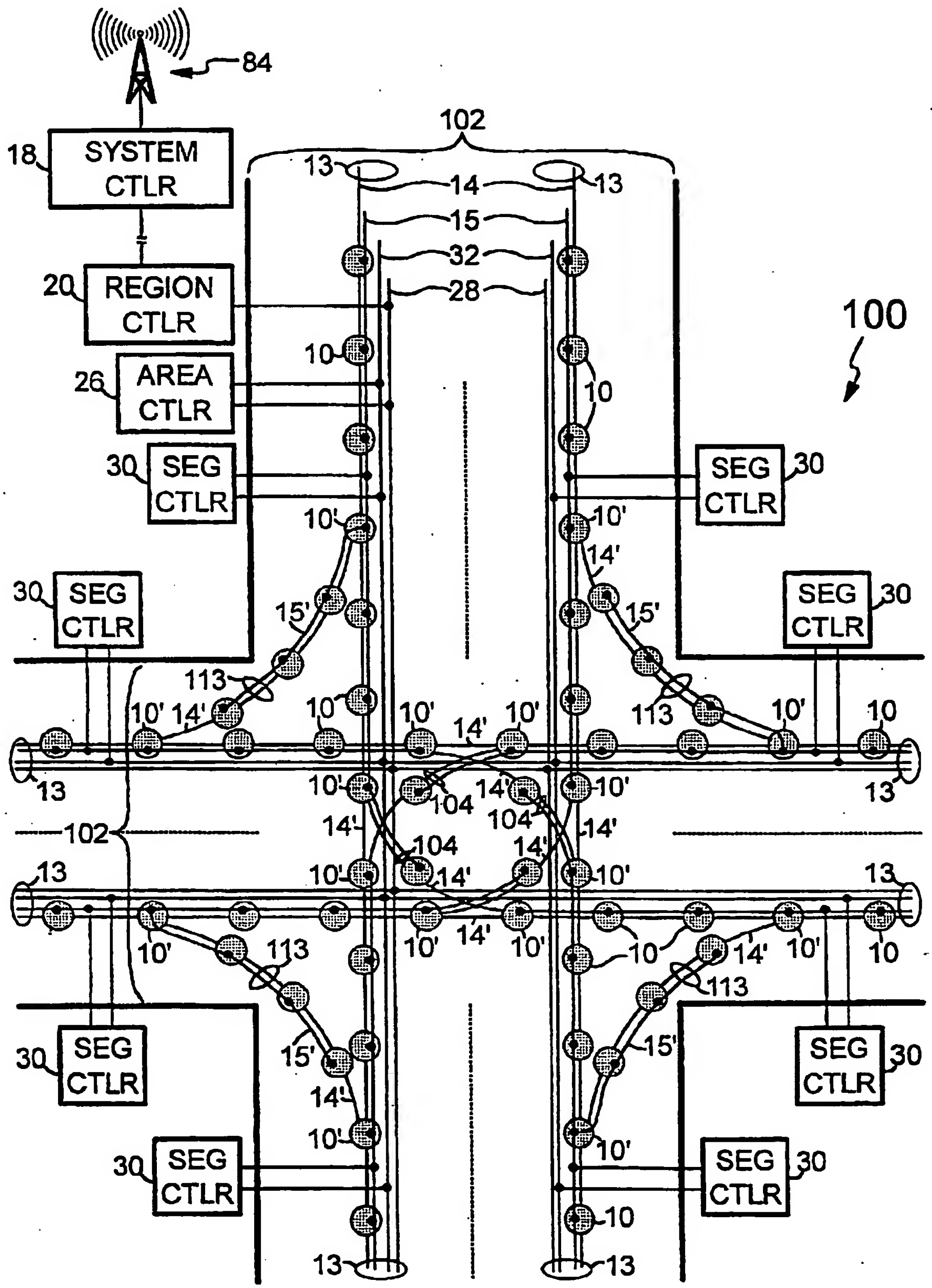
84
102
18
SYSTEM CTLR
20
REGION CTLR
26
AREA CTLR
30
SEG CTLR
100
13
14
15
32
28
10
10'
14'
15'
113
104

Fig. 10

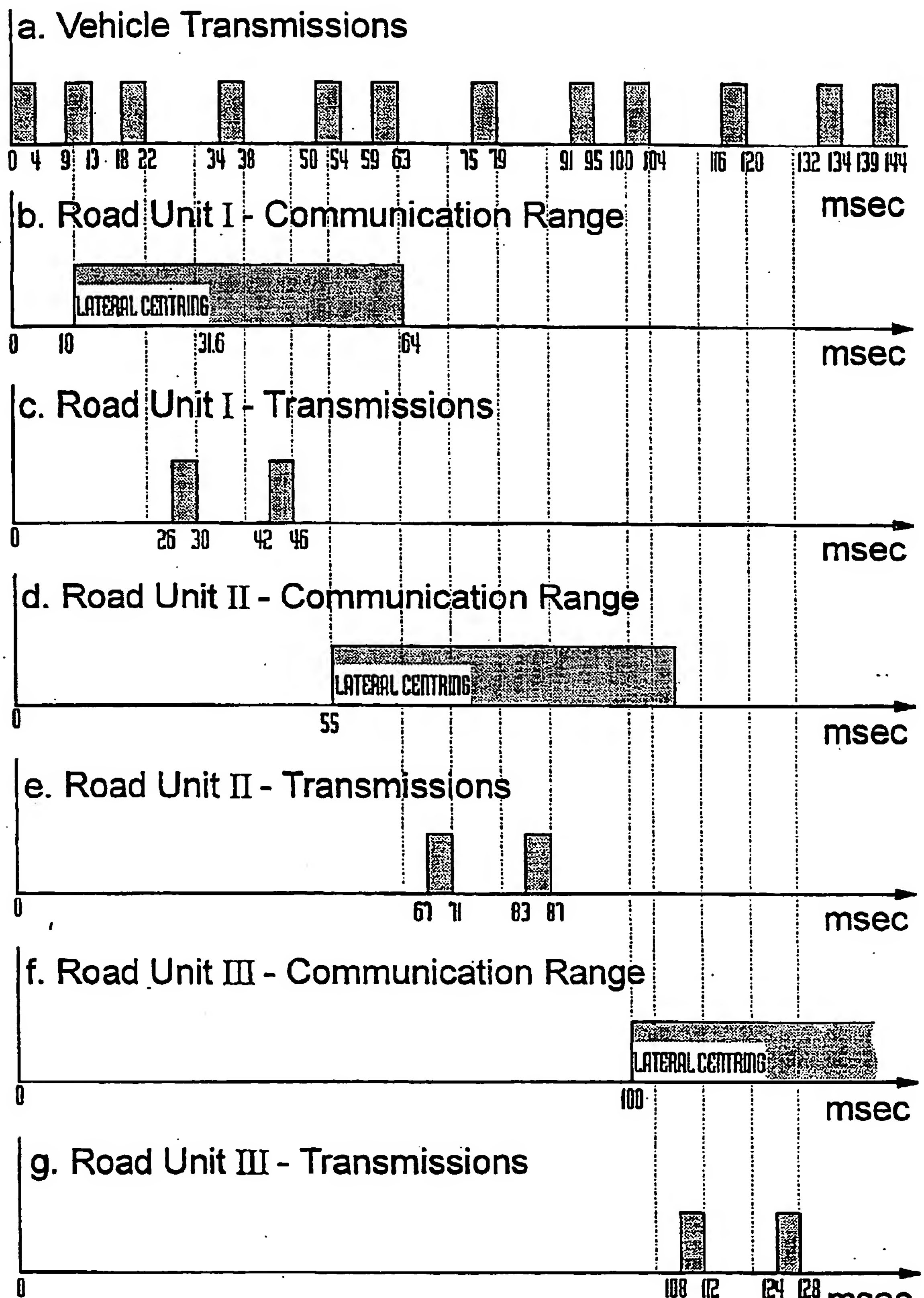
a. Vehicle Transmissions
0 4 9 13 18 22 34 38 50 54 59 63 75 79 91 95 100 104 116 120 132 134 139 144
msec
b. Road Unit I - Communication Range
LATERAL CENTRING
0 10 31.6 64
msec
c. Road Unit I - Transmissions
0 26 30 42 46
msec
d. Road Unit II - Communication Range
LATERAL CENTRING
0 55
msec
e. Road Unit II - Transmissions
0 67 71 83 87
msec
f. Road Unit III - Communication Range
LATERAL CENTRING
0 100
msec
g. Road Unit III - Transmissions
0 108 112 124 128
msec

Fig. 11

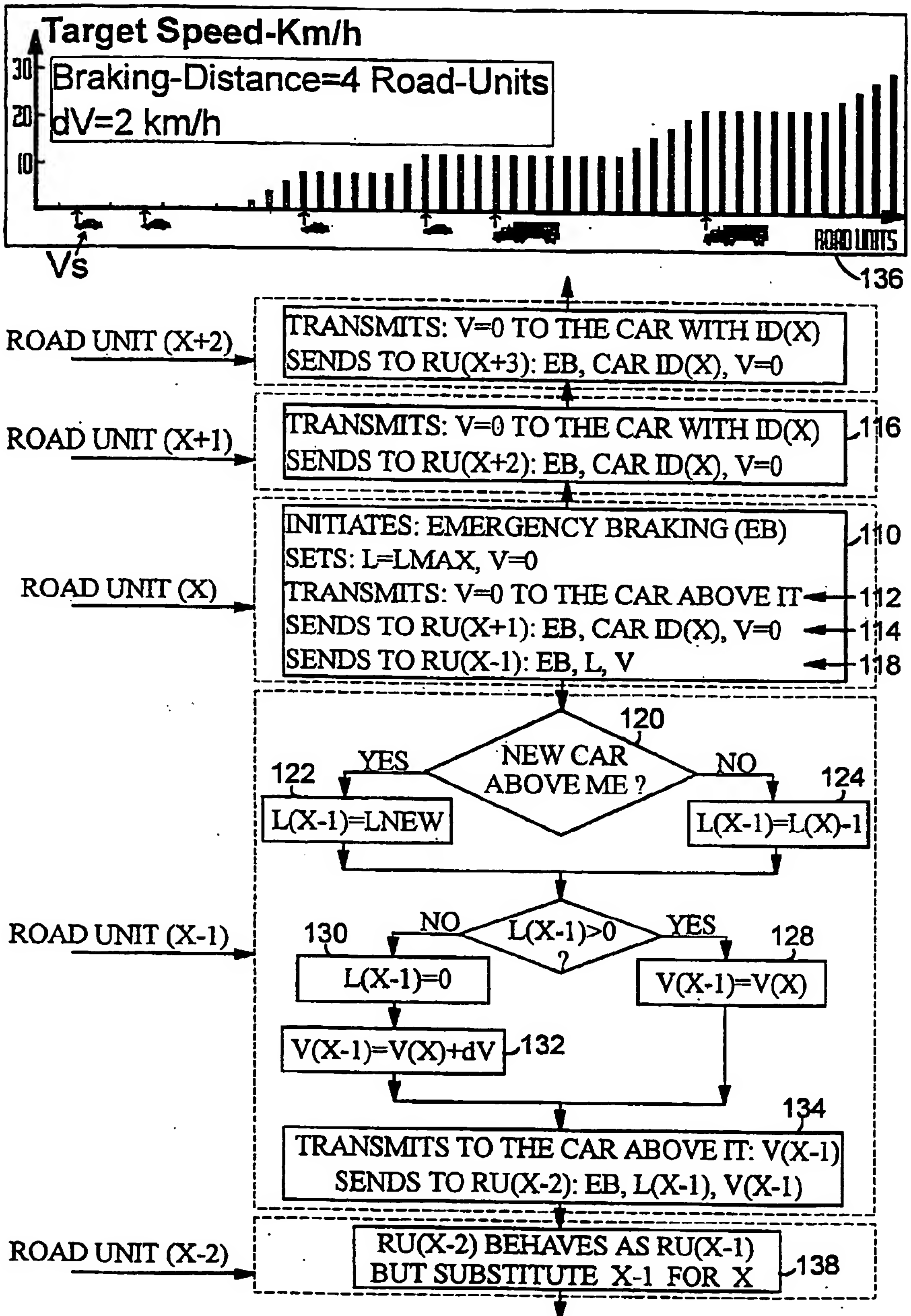
Target Speed-Km/h
30
20
10
Braking-Distance=4 Road-Units
dV=2 km/h
ROAD UNITS
Vs
136
ROAD UNIT (X+2)
TRANSMITS: V=0 TO THE CAR WITH ID(X)
SENDS TO RU(X+3): EB, CAR ID(X), V=0
ROAD UNIT (X+1)
TRANSMITS: V=0 TO THE CAR WITH ID(X)
SENDS TO RU(X+2): EB, CAR ID(X), V=0
116
ROAD UNIT (X)
INITIATES: EMERGENCY BRAKING (EB)
SETS: L=LMAX, V=0
TRANSMITS: V=0 TO THE CAR ABOVE IT
SENDS TO RU(X+1): EB, CAR ID(X), V=0
SENDS TO RU(X-1): EB, L, V
110
112
114
118
ROAD UNIT (X-1)
120
NEW CAR ABOVE ME ?
YES
NO
122
L(X-1)=LNEW
124
L(X-1)=L(X)-1
L(X-1)>0 ?
NO
YES
130
L(X-1)=0
128
V(X-1)=V(X)
V(X-1)=V(X)+dV
132
134
TRANSMITS TO THE CAR ABOVE IT: V(X-1)
SENDS TO RU(X-2): EB, L(X-1), V(X-1)
ROAD UNIT (X-2)
RU(X-2) BEHAVES AS RU(X-1) BUT SUBSTITUTE X-1 FOR X
138

Fig. 12

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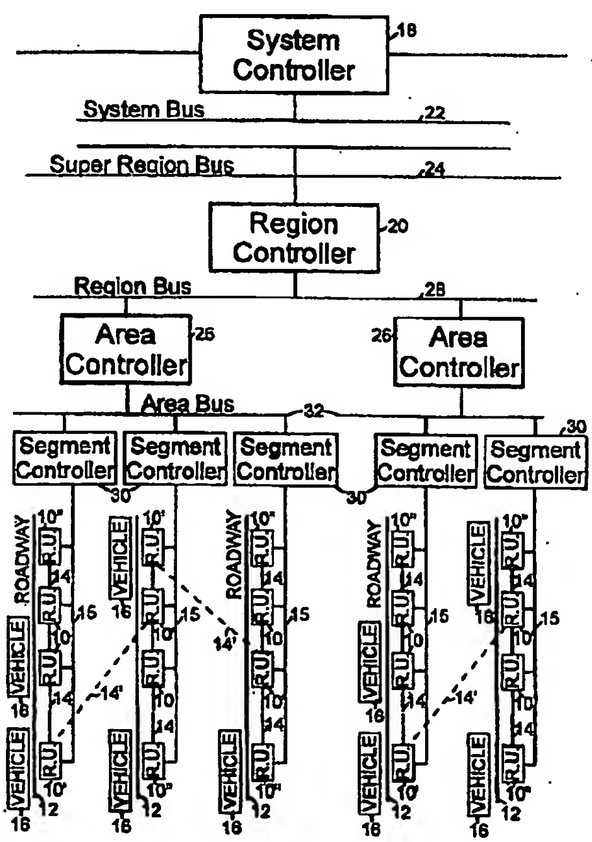
(54) Title: TRANSPORT SYSTEM

(57) Abstract

A transport system which includes a communications network and one or more vehicles each having an on-board control and data exchange unit, wherein the communications network includes a transport control unit; and a plurality of road units (10) arranged in series along a vehicle travel route, each road unit being adapted for communication with the transport control unit so as to exchange data therewith, and being further adapted for direct communication with at least two road units positioned adjacent thereto, wherein the on-board control and data exchange unit includes transceiver apparatus for communicating with each of the plurality of road units in series while traveling therepast; data processing apparatus connected to the transceiver apparatus; and control apparatus, connected to the data processing apparatus for selectably controlling and sensing any of a predetermined plurality of vehicle operating functions in response to signals received by the transceiver apparatus from the road units.



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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 95/00204

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G05D1/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G05D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,4 361 202 (M.MINOVITCH) 30 November 1982 see column 6, line 34 - line 68 see column 20, line 28 - column 48, line 23	1,3,44,45
A	FR,A,2 636 750 (SOCIETE GENERAL POUR LES TECHNIQUES NOUVELLES) 23 March 1990 see page 4, line 32 - page 11, line 24	1
A	PATENT ABSTRACTS OF JAPAN vol. 6, no. 137 (P-130) (1015) 24 July 1982 & JP,A,57 059 208 (SHINKO DENKI K.K.) 9 April 1982 see abstract	1

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3

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18 July 1995	24.07.95

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,82 00122 (SAAB SCANIA) 21 January 1982 see page 3, line 32 - page 7, line 12 ---	1
X	EP,A,0 229 669 (LITTON INDUSTRIAL AUTOMATION SYSTEMS) 22 July 1987	22
Y	see column 10, line 40 - column 11, line 39 see column 22, line 65 - column 24, line 51 ---	23,25
A	DE,A,26 31 543 (BLAUPUNKT) 19 January 1978	1,3
Y	see page 31, line 11 - page 33, line 14 ---	23,25
X	EP,A,0 482 424 (DAIFUKU) 29 April 1992 see the whole document ---	22
A	EP,A,0 330 639 (NDC AUTOMATION INC) 30 August 1989 see column 4, line 57 - column 7, line 28 ---	27-29
A	EP,A,0 367 527 (TEXAS INSTRUMENTS INCORPORATED) 9 May 1990 see figure 2A ---	23,31
A	WO,A,92 09941 (EATON-KENWAY) 11 June 1992 cited in the application see page 63, line 18 - page 66, line 3 -----	27-29

3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB95/00204

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. Claims 1-21, 44,45: transport system with a plurality of road units
2. Claims 22-43: transport system which comprises a plurality of vehicles

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searches without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int ional Application No
PCT/GB 95/00204

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-4361202	30-11-82	NONE		
FR-A-2636750	23-03-90	NONE		
WO-A-8200122	21-01-82	SE-B-	421731	25-01-82
		AU-A-	7325881	02-02-82
		CA-A-	1156333	01-11-83
		EP-A-	0062644	20-10-82
		US-A-	4464659	07-08-84
EP-A-0229669	22-07-87	NONE		
DE-A-2631543	19-01-78	JP-C-	1682626	31-07-92
		JP-B-	3037240	04-06-91
		JP-A-	53037293	06-04-78
		US-A-	4251797	17-02-81
EP-A-0482424	29-04-92	JP-A-	4160413	03-06-92
		JP-A-	4162108	05-06-92
		JP-A-	4182709	30-06-92
		JP-A-	4182708	30-06-92
		CA-A-	2053028	24-04-92
		US-A-	5267173	30-11-93
EP-A-0330639	30-08-89	NONE		
EP-A-0367527	09-05-90	US-A-	5280431	18-01-94
		JP-A-	2244207	28-09-90
WO-A-9209941	11-06-92	US-A-	5281901	25-01-94
		AU-B-	657653	16-03-95
		AU-A-	9112791	25-06-92
		CA-A-	2095442	04-06-92
		EP-A-	0560881	22-09-93
		US-A-	5341130	23-08-94

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